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British Official Photo

The church at Merville, a monument of Germanic atrocity

A VISIT TO THE BRITISH FRONT IN SEPTEMBER [See page 344]

Life and Light*

The Process by Which Living Organisms Produce Light

By Raphael Dubois, Professor of General and Comparative Physiology at the University of Lyons

Luminous creatures are found in almost every degree of the scale of living organisms, from the infinitesimal microbe up to the vertebrate. They live in the most diverse environment in every part of the globe and even at the lowest depths of the ocean.

From the remotest antiquity this marvellous natural phenomenon has excited the enthusiasm of poets, and even more so the curiosity of countless scientists, including many of distinction. The bibliography of this question is enormous and would alone fill a very large volume. Even in 1835 Ehrenberg cites no less than 436 authors who wrote exclusively upon the luminous animals of the sea, and in 1887 Henri Gadeau de Kerville mentions 336 works dealing entirely with luminous insects. These two examples indicate how extensive have been the researches connected with the study of biophotogenesis, which constitutes one of the most interesting chapters of general physiology, i. e., the phenomena of the life common to plants and animals. It ranks beside bioelectrogenesis, or the production of electricity, and biothermogenesis, or the production of heat, by living creatures.

The number of hypotheses proposed to explain the secret of this marvelous phenomenon is likewise very considerable, and all these works and these hypotheses indicate not only the interest with which scientists have always endeavored to find the solution of this problem, but also its excessive difficulty. Certain naturalists have found it so insurmountable and so much beyond the scope of general scientific sagacity that Professor Joubin, of the Museum, declared in the address which he made in 1911, upon the occasion of the ceremonious inauguration of the Oceanographic Museum at Monaco, that another Becquerel was required to unravel this riddle. But the problem had already been solved in the completest manner, as I was able to demonstrate publicly in the course of the International Congress of Zoology which followed the opening of the Museum. Moreover, this demonstration was made in the laboratories of the Oceanographic Institute itself, which its learned and obliging director, M. Richard, kindly placed at my disposal. This demonstration, which was made in the presence of M. Richard, consisted not only of a verbal explanation, but also of conclusive experiments to the accuracy of which no objection was raised. This demonstration was also repeated in the presence of several heads of departments of the Institute, and in particular of our own eminent biological chemist, Professor Armand Gautier, whose entire competence to judge especially in this field is incontestable. Finally, my experiments have been frequently repeated, and always with the same success, before a large number of French and of foreign scientific societies, for example, at the International Congress of Physiology at Groningue, and in public lectures before large audiences, in particular at the Congress of French and English Associations for the Advancement of the Sciences, which met at Havre, in August, 1914.

In order to remedy the serious inconveniences arising from partial studies, which often lead to erroneous conclusions, and also by reason of the action of the Commission of the French Academy of Sciences, which in 1887 did me the honor of bestowing the Grand Prize of Physical Sciences on my work upon the Luminous Elateride[1], I have undertaken a general study of biophotogenesis throughout the whole series of plants and animals. In this article I must confine myself to a mere résumé of the question elsewhere treated in detail[2].

I. The Function of Biophotogenesis in the Plant and Animal Series.

In the vegetable kingdom biophotogenesis has been observed with certainty only in the achlorophyllian organisms, and among these only in the two groups of the *Hyphomyceics* and the *Photobacteria*. The latter are highly polymorphous and very "polybial." About thirty species belonging to five or six genera have been pointed out by botanists, but because of the polymorphism and their "polybiosis" all rational classification is impossible, and perhaps we may provisorily place them all in the genus *Photobacterium* and in the species *Photobacterium sarcophilum* Dubois, which may present itself in very various mobile and ciliated forms as well as in immobile, nonciliated forms. Photobacteria may be luminous or not according to the condition of the medium in which they exist, a fact which proves that the photogenic function is not indispensable to the vital functioning of these organisms. This property cannot even serve as the basis of a strictly exact classification. Among luminous plants the photogenic function, though closely connected with that of respiration, is not dependent upon the latter. It is not localized in special organs. In these organisms the photogenic substance is destroyed as fast as produced, contrary to what occurs in other creatures, because their light being continuous does not permit of the accumulation of photogenic products during periods of repose. This circumstance explains the lack of success of certain investigators, among others James Dewar, in their attempts at extraction.

In the higher photogenic Fungi nearly all portions of the plant, but especially the hood, may shine with a continuous light, which is sometimes very brilliant. The mycelium of several species is luminous, and it is this which often lends a phosphorescent glow to decayed wood.

Among the *Protozoa* the photogenic function is not localized in clearly defined portions; but neither is it absolutely diffused, by which is meant that it manifests itself in the form of isolated sparks, corresponding to the characteristic granulation found in all the photogenic organs of the Metazoa. The quality of irritability or excitability, which seems to be present very slightly or not at all in luminous plants, becomes of great importance in the *Protozea* which respond to excitations by the emission of luminous radiations. The photogenic function is enfeebled by fatigue, whatever its cause; however, the production of the light survives the excitability and even the somatic life of the individual.

These little microscopic organisms sometimes produce enormous quantities of light; for example, in the phosphorescence of the sea of which they are the most usual cause. Among the *Coelentera* irritability plays a large part in the luminous response to an excitation, but the photogenic phenomenon may exhibit itself when the irritability has ceased to exist; it tends to localize itself, for example, in the luminous mucus of the cells of the epidermis, which are more or less differentiated into secretory elements, and also in the organs functioning as genital glands in the adult *Coelentera*. The photogenic function exists even in the egg and in the larva. The ultimate and fundamental seat of the luminous reaction may be readily localized in the granulations to which I have given the name of vacuolids,[3] and which can easily be made to appear in certain circumstances. By their disaggregation the *Coelentera* sometimes produce the *phosphorescence of the sea*.

Among worms, as in the Echinoderms, the photogenic function takes the character of an external glandular secretion. The phenomenon is found at a very early period in the larvæ, and probably already exists in the egg.

The *crustacea* present two sorts of luminous organs: 1. Photospheres composed of an internal secretion photogenic gland connected with large sanguine sinuses, and provided with accessory and perfecting apparatus such as reflectors and lenses; 2. External secretion photogenic glands with or without reservoirs and an excretory duct, surrounded by sanguine sinuses, with which they are closely connected. The rôle of the muscles in the irrigation of the sanguine sinuses is likewise evident and enables us to understand the *indirect* action of the nervous system upon the functioning of the photogenic organs.

Among the *Thysanura* and the *Myriapods* the photogenic function is localized in external secretion glandular organs. The excreted product can be extinguished by desiccation, and long afterward the light can be revived by the addition of a little water. In the midst of the luminous mucus secreted, crystals are formed and these are concerned with the intimate mechanism of the photogenic function.

Among Insects this function already appears in the egg, even before fecundation. Later it becomes localized in the ectodermic cells of the blastoderm. Hence the tracheas are not necessary to its existence as has been erroneously maintained by a great many scientists. It is the ancestral torch which passes without being extinguished for a single instant from the egg to the larva, to the nymph, to the perfect insect and from this to the egg once more, and this unbroken succession continues for century after century.

In the adult insect the photogenic organs are typical internal secretion glands. So long as the blood does not come in contact with the glandular elements the light is feeble or lacking; but when the blood rushes into the tissues of the internal gland, the light makes its appearance and glows brightly. This entry of the blood is regulated by the muscles. The latter, in their turn, obey the motor nerves, and these by the intervention of the ganglions concur with the reflex act, whose point of departure is in the sensory nerves or in their sensorial terminations. The intrinsic and extrinsic muscles of the photogenic apparatus are striated and may also obey directly the nerve centres of the will.

As elsewhere, but perhaps with more activity, they insure in the photogenic apparatus oxygenation by means of the blood, whose entry and circulation in the glandular sinuses they regulate. Tracheal ventilation may easily be suspended at the moment when the light appears in the luminous organs. The action of the blood, therefore, is primordial and preponderant.

The light-producing reaction is thus localized in the cells of the organ, which are evidently in process of secretory disaggregation or glandular breakdown. They are crowded with these granulations, which are found in all luminous organs, and which I have termed vacuolids, elementary granulations of all living substance; in Germany these have been called *mitochondria*, while the name *Vacuolid* which I gave them in 1886, at the time when I discovered them, indicates much more precisely their morphologic structure, which enabled me many years ago to demonstrate their analogy and homology with the vegetable leucites,[4] a conclusion which has since been confirmed by the researches of Pensa, Lewitsky, Fauré-Frémiet, Mulon, etc., and by two of my pupils at Lyons, MM. Guilliermond and Regaud, among others. These vacuolids contain the photogenic principle *luciferine*.

It is possible to completely crush the cells of the light-producing organs, entirely destroying all cellular organization, without checking the production of the light. When the photogenic substance is crushed and diluted with water it still passes through a paper filter as a luminous liquid. When this substance of the luminous organ is rapidly dried it is extinguished, but it may be reilluminated by moistening it with water. Organs extinguished by heat at about 60°C., and then crushed, cease to give light even in contact with water and air, but they are reilluminated when pulverized with organs extinguished in the cold by prolonged trituration.

The luminous phenomenon is not of cellular nature: it is produced by a double reaction of zymasic nature, a fact which I established by my experiments upon the *Pyrophora* of the Antilles in 1885. The brilliance of the light is modified and re-enforced in their luminous apparatus by fluorescent substances which transform useless or injurious dark radiations into luminous radiations (Luciferesceines).

Among the *Mollusks*, and even in the single class of the *Cephalopods*, two types of light forming organs are found: 1. Internal secretion glandular apparatus like those which occur for the first time in Insects; 2. External secretion photogenic elements. This last type yields in the dactyloid Pholas, an abundant secretion of luminous mucus, and it was this exceptional circumstance which enabled me to solve completely and definitely the problem of the intimate reaction which gives birth to physiologic light.

In the branch of the *Tunicata* we find again the immortal ancestral torch transmitted from the adult

*Translated for the Scientific American Supplement from *Revue Générale des Sciences*.

[1]Theses of the Faculty of Sciences of Paris and Bulletin of the Zoological Society of France, 1886.

[2]See Life and Light (La Vie et la Lumière), vol. I., of La Bibliothèque Internationale, 338 pages, 48 fig., Félix Alcan, Paris, 1914; and Intimate Mechanism of the Production of Light in Living Organisms.—Critical Examination of the Question of Biophotogenesis.—Concerning the Place of Biophotogenesis, Ann. de la Soc. Linn. de Lyon, published by Rey in Lyons, 1913 and 1914.—Grande Dictionnaire de Physiologie, by Richtt: article on The Production and Action of Light (in press).

[3]Life and Light (La Vie et la Lumière), loc. cit., see Introduction, page 5 and following pages.

[4]See Lecons le Physiologie Génerale et Comparees), Masson, Paris. 1898, pp. 70 and 78.

to the egg, from the egg to the larva, and from the larva to the adult, for ever and ever without ever being extinguished, like the fire of the Vestals. In the *Tunicata* also the light is always furnished by ectodermic elements, by glands surrounded by large sanguine sinuses; in these elements Julien has found granulations which he calls mitohondria and which are nothing other than my own vacuolids, which once more proves their identity and my priority of discovery of the true structure of protoplasm, or rather of *bioproteon** as I prefer to call it. As for the photogenic substance, it behaves among the *Tunicata* as it does everywhere else.

Among the *Fishes*, i. e., among the most differentiated photogenic organisms, we find a general repetition, so to say, of all that we have seen in the lower degrees of the scale of living creatures. It is in this branch especially that we are able to follow, step by step, the evolution of the light-producing organ, from the simple epidermic cell, bare and superficial, up to those curious eye-shaped apparatus which are the most highly complex photospheres, with their organs of concentration and of reflection, their diaphragms, their screens of adaptation and of accommodation, and even their apparatus of orientation. It is in the study of luminous Fishes that the most brilliant confirmation is found of the unity of the fundamental processes of the intimate biologic mechanism which general physiology reveals to us, but whose simplicity is usually masked by devices to secure improvement or adaptation, and which only comparative physiology enables us to discern.

As for the existence of normal or physiologic biophotogenesis stated to exist among vertebrates higher than fishes, it needs to be proved by fresh observation. It is desirable, likewise, that pathologic biophotogenesis should be made the object of a special study. It may be that glandular secretions, such as milk, perspiration, or urine, sometimes furnish luminous liquids aside from any parasitic infection; but in the great majority of cases observed in wounded or dying persons or in corpses it seems quite certain that the phenomena observed were accidental, and caused merely by parasitic photobacteria. *To sum the matter up the important thing to remember is that the physiologic function of the production of light is everywhere reductible to a process of glandular secretion furnishing photogenic products.*

II. THE PHYSICAL PROPERTIES OF PHYSIOLOGICAL LIGHT.

Physiological light is chiefly constituted by rays of average wave lengths, i. e. by the most luminous rays of the solar spectrum. Direct optical examination proves that this light is indisputably superior for purposes of vision to the rays from all other known sources. It contains very few chemical radiations and only minute quantities of heat radiations. These facts cannot be attributed to the feebleness of these sources of light nor to absorption by the apparatus employed. We have here, in fact, a special kind of light, *cold light*, in the term given it by me.

From the economic point of view its yield is almost 100%, and the expenditure of energy required is as low as possible. My experimental results and my conclusions have long been confirmed by eminent physicists, among others by Very and Langley in America.

In certain cases its intensity is reinforced by fluorescent substances (Luciferesceines) which, while transforming a part of the useless or even injurious chemical radiation add to the other physical and organoleptic qualities of this marvellous light a peculiar and beautiful brilliance. As we know, this improved economical process, discovered and described by me in 1886 in the brilliant Pyrophora of the Antilles, has since been utilized in industry, especially to correct the inconveniences and increase the yield of mercury vapor lamps. Thus in this respect the insect preceded man, and the latter, indeed, is still far from equalling the former in the manufacture of illumination. These considerations led me in 1900 to make public tests of physiologic cold light as a means of illumination at the Palace of Optics in the Paris Exposition. For this purpose I made use of photobacteria or luminous microbes, employing them particularly in the *living lamp* which bears my name.

This means of illumination is capable of immediate application; this, however, is very restricted because of the insufficient intensity of the light which does not exceed that of fine moonlight. Besides the superior physical and organoleptic qualities of physiologic life the "living lamp" has other advantages. The expense of maintaining it is extremely low, and it requires no care for weeks at a time; it produces no annoying heat and also offers no danger of fire. Furthermore, this lamp fears neither wind nor rain and gives off no disagreeable or deleterious vapors. It requires no conducting wire and no system of pipes and it is very light and can be easily moved from place to place. I believe that it would not be impossible to increase its power of illumination, and could this be made sufficiently great no other source of light would compare with it. In any case, the study of the biophotogenic function in plants and animals clearly shows the superiority and the possible attainment sooner or later of *illumination by means of cold light.*

In many cases it is impossible to define the usefulness of physiological light, but in others it manifestly serves to assist the functions of locomotion, prehension, defence and reproduction. Moreover, the photogenic reaction, especially in the case of the internal secretion, may be intimately connected with some internal process of nutrition which is useful, though not indispensable; among the Pyrophora, for example, there exists side by side with very brilliant species another which has no light, and I have succeeded in removing from the glow worm its luminous organs without interfering with the development of the insect.

III. REDUCTION OF THE BIOPHOTOGENIC FUNCTION TO A CHEMICAL PHENOMENON.

By processes for whose details I must refer the reader to the works cited at the beginning of this article, I have succeeded in isolating two perfectly definite chemical substances which by their contact in the presence of water yield *in vitro* the same light as that given forth by living photogenic organs. I have called these substances respectively *luciferase* and *luciferine*. Their separation, their purification, and their preservation require delicate manipulations which need not here be described. I will content myself with giving the principal chemical characteristics of these two substances.

Luciferase.—This is not destroyed by a one per cent. solution of sodium fluoride, which excludes the idea of a cellular or micro-organic property; it passes readily through filters made of paper, but very scantily through those of porcelain, and does not undergo dialysis. It decomposes hydrogen peroxide energetically; heat increases its photogenic activity with an optimum effect comprised between 30°C. and 40°C.; it is destroyed at 60°C. It resists the greatest cold and its aqueous mixture with luciferine continues to shine at 5°C. below zero, but more feebly than at temperatures above zero.

Neutral salts and sugar in concentrated solutions suspend without destroying its activity, which is regained upon sufficient dilution with water. Strong alcohol precipitates it but also destroys it, like the oxydones. It is slowly altered by chloroform, ether, acetone and formol. Luciferase presents moreover all the general characters of proteic substances, and exhibits itself in the tissues under the vacuolid form. It contains neither manganese nor copper, but does contain concealed iron: it is a ferric *zymase*.

Its specific characteristic is the giving of light with luciferine in the presence of aerated water. In this reaction it can be replaced by a non-zymasic chemical compound, such as permanganate of potash, dioxide of lead or barium dioxide, and especially by luciferine which has first been treated with a few drops of hydrogen peroxide and then with a little protosulphate of iron, or ammoniacal citrate of iron, to which a little ammonia has been added, or still more simply with a little blood or hematine. These reactions suffice to establish the fact that it acts as an oxydizer, but this can also be demonstrated by its action upon guyacol, pyrogallol, quinine, chlorhydrate of diamidophenol, Tromsdorf's liquid blued by a trace of sodium nitrite and sulphuric acid, etc.

Luciferase, therefore, is an oxydase, but one of very special type, resembling the peroxydases in some respects and the oxydones of Stern and Battelli in others.

Luciferine.—This substance exhibits the specific characteristics of *natural albumens*, which need not here be enumerated. Luciferase has the definite function of borrowing oxygen from the surrounding medium and combining it with luciferine. The bio-oxyluminescence therefore requires not only water and oxygen, but also a substance *indirectly* oxydizing the luciferine. There is no direct oxidation here as in the case of phosphorus and of certain volatile organic compounds which become phosphorescent in the presence of air. In the aqueous medium in which the reaction between the luciferase and the luciferine takes place, crystals are formed of the same kind as those which are observed in photogenic secretions, being particularly abundant in that of the *Orya barbarica*, a phosphorescent Algerian Myriapod.

When we produce a reaction *in vitro* between the purified luciferine and luciferase, we observe the appearance of an infinite number of minute rounded granules, altogether similar to those found in the Noctiluca, in the luminous organs of Insects, etc. These granulations, which are non-photogenic when separated by centrifugation, give the xanthic reaction: they proceed from the oxidation of luciferine.

My most recent researches, particularly those relating to the dactyloid Pholas and its luminous secretion, confirm at all points the conclusions of my former studies upon the Pyrophora noctiluca.

Luciferase and luciferine, which are very alterable in a pure state, can be kept for a long time, either separate or mixed, in solutions of salts or of saturated sugar. It is only necessary to pour a little of the syrup containing a mixture of these two substances into a glass of water to obtain an excellent night light. Since these photogenic substances are not at all poisonous one might, in case of necessity, drink his bedside lamp or use it to put out a fire. Unfortunately, the photogenic reaction does not last very long, and its illuminating power is not very great. However, it is strong enough to enable one to read the face of a watch and ordinary print, etc. It is to be noted that the illuminating power of the luminous organs removed from the most brilliant animals becomes much feebler when these organs are crushed, which proves that in the living animal this power is enhanced by some perfecting device whose nature is as yet unknown; this fact leads us to believe that the luminescence of the luciferase-luciferine reaction, or of analagous reactions, can be artificially reinforced, and possibly some such means of reinforcement may provide us in the future with a practical means of illumination by means of cold light.

The ultimate phenomenon of cold light produced by physiologic means must take its place among those which Wiedemann has grouped under the name of *luminescences*, and which are divided into a certain number of classes.

Since biophotogenesis can be obtained in the last analysis outside any cell or fragment of a cell, *in vitro*, by a double reaction in the presence of water and of air, it may be classed in the group of *chemi-luminescences;* at least, if we admit that the luciferase is still a living thing, since the zymases exhibit most of the properties of *bioproteon* (protoplasm) or living substance. It would be proper, according to this view, to retain the group of *bioluminescences*. Otherwise, this luminescence may be considered as belonging to the sub group of *chemi-luminescences by oxidation, or oxyluminescences*, and to the category of the *zymo-oxyluminescences* represented solely thus far by the oxidation of luciferine by means of luciferase.

In 1886, when I first discovered this phenomenon, other phenomena of oxyluminescence were already known, but these were purely chemical, such as that of phosphorus and that which accompanies the heating of fatty bodies in certain pharmaceutical preparations.

Radziszewski has also shown that alcoholic potassium, and even other alkalies, are capable of yielding a cold light by the oxidation of certain organic substances (Lophine, for example). But this chemist made no experiments upon luminous plants and animals.

It is quite possible that several varieties of luciferase and of luciferine may exist, but in any case these are only varieties, and the biophotogenic process is similar in all respects.

Among certain animals organic perfecting devices are found which greatly increase the illuminating power of the photogenic reaction. In closing I may remark that it can safely be affirmed today, without fear of contradiction, that the problem of biophotogenesis in its last analysis has been solved, since it concerns a *chemi-zymo-oxyluminescence* produced by definite chemical compounds.

*I have substituted this expression for the word "protoplasm" because the latter has an ambiguous meaning, and because it is related to my unicist theory of Proteon, a unique principle representing in the last analysis both force and matter, which are only two different aspects of the same thing.

Cosmology Among Natives of South Africa

The Rev. S. S. Dorman discusses native ideas of cosmology in the *South African Journal of Science* (vol. XIV, No. 4, November, 1917). The origin of these is obscure, but the writer remarks that the Abenanswa may be a mixed remnant of the old Hamitic stock; Semite and Hamite are very closely related both in blood and language, and very probably had the same or similar legends of Creation. If so, the Abenanswa, like the Masai, could have derived their legends from the north, and the Bantu may have learned them in a more or less complete form. But, on the whole, the writer leans to the conclusion that the Bantu ideas of cosmology are purely their own, and are thus an index of the mentality of that race.—*Nature.*

A Silky Eater of Ants*

A Tiny Animal of Exclusive Tastes and Peculiar Habits

By William Beebe

THREE million years ago a perfectly good white ant lived on the earth. His fossilized remains have been so well preserved that there is no doubt of his presence and activity in that dim, distant past. Together with many of his fellows, he left the impression of his body in the mud of that far off time, and since then the mud has hardened to stone, been buried under thousands of centuries of other mud and stone, and at last split open by inquisitive scientists and the ant impressions recognized from their striking resemblance to their rather distant relatives living on the topmost stratum of the earth today. Hence my right to the adjective "white" in referring to fossils, an adjective of considerable importance, as it indicates that these insects are not really ants at all, and removes them from Soloman's entomological advice, in identity although not in unworthiness. For white ants or termites are related much more closely to dragonflies than to ordinary ants. Though today they have developed a marvellously intricate social life, yet they and their relatives trace their lineage back with almost no change in structure an unthinkably longer time than man and his immediate forebears have taken to evolve.

I have devoted this whole paragraph to the white ant because of the importance of his relation to my subject from quite another viewpoint—a rather unkind one—that of the food which he, and his billions of brethren, scattered over all the face of the world, furnish to hosts of animals, birds, reptiles and ant-eaters in particular. True ants, Soloman's kind, which make slaves and wage wars, are devoured by many creatures, but these insects are all flavored more or less strongly with formic acid, and must be an acquired taste. White ants or termites, on the other hand, are, by all insect-eaters and some others, considered a universal panacea for hunger, and I have seen fishes leaping for them, lizards risking dangers from hawk and man, dogs, cats and Bornean squirrels snapping up the winged hosts, while they furnish by far the larger proportion of food of pheasants and many other birds. The little Malayan bear has been recorded several times as clawing apart their nests and feeding upon these insects, although the amount of debris which must be included, makes this an exceedingly adulterated diet.

"Having obtained a firm grip with both hind feet, the little creature bends forward"

Termites are today so important an article of diet on the earth, that certain animals have been developed with this sole means of nourishment in view. I have already related something of the scaly ant-eater of Borneo.[1] In South America, where these insects are exceedingly abundant, there are three animals set apart from all others in structure and mode of life, to which the ants are actually *la raison d'etre*. They would probably become extinct or at least hard pressed for food were the supply of termites and ants to fail for a few weeks.

Some of the white ants build their nests in trees, others are content with lowlier positions; some of the nests are large and extremely hard, some are smaller and less cement-like, while still lesser structures are not lacking which offer but little resistance to outside force. Like the various sizes of big and little bears, we find three types of ant-eaters adapted to the varied building sites and the durability of the ant nests.

Silky ant-eater

"At a touch, the little creature assumes a most remarkable attitude"

These three animals whose forms and activities have been moulded upon a single article of diet are the Great Ant-eater or Ant-bear *(Myrmecophaga jubata)*, the Lesser Ant-eater or Tamandua *(Tamandua tetradactyla)*, and the Little Silky Ant-eater *(Cyclopes didactylus)*. It is said that the latter occasionally feeds on the larvæ of ants and wasps, but this has not been confirmed. All three are found about our tropical research station in British Guiana and all have now been represented by living specimens in the Zoological Park. Perhaps the best known is the largest, which is by no means innocuous, although its diet is of so humble a character. No man, single-handed, could overcome an ant-bear, so strong are its muscles and so effective its claws. The last one observed in our vicinity was killed at the Penal Settlement by Mr. Frere, which from nose to tail-tip measured exactly eight feet. This species is wholly terrestrial and is occasionally to be seen making its way through the jungle or along the Indian trails, or, as I have twice observed it, swimming wide rivers and creeks. The head, and the long hair of the back and tail project above the water, and the creature makes surprisingly good time.

The tamandua or lesser ant-eater is less frequently seen and always in trees. Last year one was discovered rolled up in a ball resting in a low crotch. He was picked out and we kept him alive.

The Pygmy or Silky Ant-eater is by far the rarest of its family. There are few specimens in museums and not one has been brought alive to a northern zoological garden. In July, a year ago, as I paddled along a jungle creek I saw my first Silky Ant-eater. It was an overcast, late afternoon and the little creature had begun her hunting early, climbing slowly along a branch overhead. I was quite certain of her sex, for I could distinctly see a young ant-eater clinging to her fur, half beneath and half to one side. I had no gun, so could only watch her through my glasses and curse the horde of stinging ants which made any ascent of the tree impossible.

A boviander gold miner was descending the lower Cuyuni rapids late in September of the present year, when an unexpected eddy swung his boat toward shore, and it crashed into some bushes. When he had pushed out again into the still water below, several small boughs remained on board. On one of these was a round ball of fur, which, when poked, turned toward the man with such a comical, supplicating gesture that he laughed and allowed the small creature to remain.

When the Penal Settlement was reached I lifted the little ant-eater carefully and received the same ludicrous salaam. This was the first living captive specimen of which I ever had heard, so I devoted myself to making him comfortable, both outside and in.

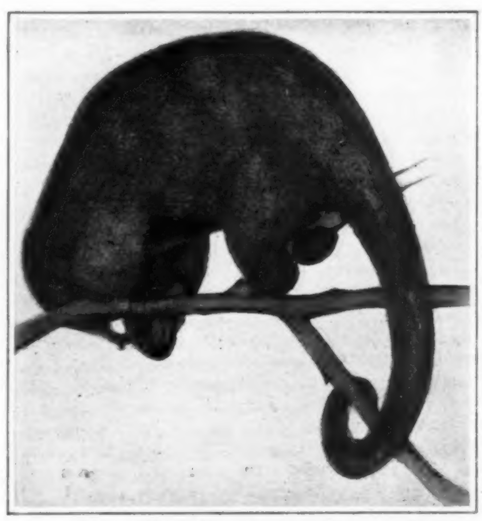
His external wants were simple in the extreme—in comparison those of Omar were complex, with only the bough in common, and this to sit upon and not under. He was happy in a cubic foot of space throughout the day, and unless disturbed never moved from the spot he had chosen at dawn. No circle plotted by mathematician could be rounder than this small being when engaged in passing the useless hours from dawn to dusk. For him the sun is a wholly useless member of the planetary system, light is an evil thing, day something to be forgotten in sleep.

Having obtained a firm grip with both hind feet upon a branch, the little creature bends forward and down, until nose and all four feet come together. Then the long prehensile tail curls around, so evenly that without unwinding it, one cannot tell on which side it starts or ends. It is always curled from the right side around in front of the feet, behind the left leg.

From here on, the bare, pinkish-red tail-grip forms a tiny cup between the feet, in which the sensitive little nose is safely buried. The palms of the forefeet are pressed together, which brings the inbent, twin claws of those limbs close above the face, thus effectively shielding all the delicate parts of the body.

Homer describes the Cyclopes of old as gigantic troglodytes, cannibals with a single eye, living a pastoral life in the far west, ignorant of law and order, and fearing neither gods nor men. With our modern little spherical *Cyclopes* we can find no parallel, except as to the final phrase. But though more prosaically arboreal, insectivorous, *et avec deux yeux*, yet the Silky Ant-eater is not an unworthy namesake.

At a touch, at a trembling of the branch, the little creature straightens up and assumes a most remarkable attitude. The tail takes a tight grip about the branch. Both arms are raised in front of the face, the red soles and the bright pink muzzle showing as three strange bits of brilliant color. The claws are laid along the snout back of the tip, and this weird posture brings to the imagination thoughts of some



"Nose and all four feet come together"

strange gnome performing an equally strange religious rite, or an eery dwarf going through the movements of some unknown, silent dance.

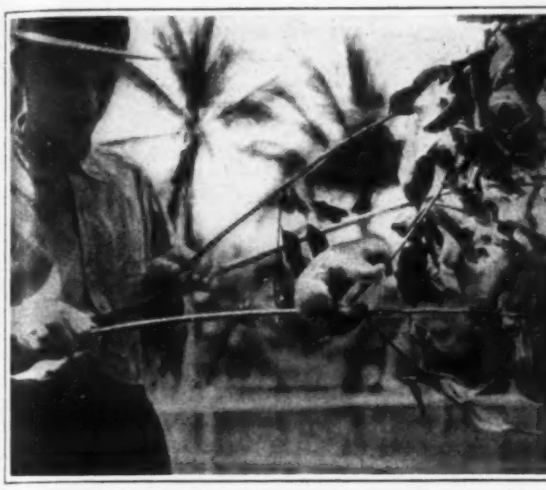
Thus swaying from side to side, in slow inexplicable rhythm, the little ant-eater awaits further attack on the part of his disturber. At the least touch on the upraised palms or the snout, both limbs are brought down as quick as a flash, and one has to be on the alert to avoid getting a vicious slash from the strong claws which, like stilettos, shoot forth from the line of the snout.

If the disturbance is severe, the creature puts its whole back and body into the blow and the claws come down on the branch or anything which intervenes with most surprising force.

My assistant incautiously received a slight scratch from such a stroke, and required two weeks' treatment

*From the *N. Y. Zoological Society Bulletin*.

[1] Zool. Soc. Bull. XVII. No. 5, p. 1,141.



"No matter how much he is teased, not a sound escapes him"

to avoid blood poisoning. Although thus quiescently awaiting attack, the Silky Ant-eater is far from being unarmed, even in addition to his claws. His thirty-two ribs are widened and flattened until they form a veritable box of bone, and with the dense, matted coat of fur, must offer an almost perfect protection to an attacking snake, small owl or carnivore. Though concealed beneath a camouflage of fur, yet the ribs protect the vital organs as completely as the external plates of the scaly ant-eater or the armadillo.

The color of the fur on the body of this ant-eater is, in general, a grizzled buffy grey, the hairs being long, dense, and with a silvery gloss. On the head and legs and tail this becomes a cold grey. A narrow blackish-brown line on the crown broadens suddenly on the neck and back, narrowing and dying out on the lower back.

These colors and patterns are emphasized on the under surface, and, added to the rosy spots of color of the soles and muzzle, give it an undescribably strange aspect. The sides below are yellowish buff, while toward the center this color changes to whitish grey. Down the full length of the body in sharp contrast with the surrounding hues extends a broad black line, of even width, except where it widens out on the throat. This sturdy little erect column of grey, yellow and black fur, apparently faceless, topped by a triangle of red, is like nothing else in the world, and when at a tap on the branch it suddenly arises from a mass of green leaves, all efforts at similes or exact descriptions are hopeless.

His eyes are black, prominent and mouselike. When open wide they are quite round, but more often they are mere slits or are closed. Strangely enough the latter is the case at the moment of expected attack, the ant-eater preferring to shelter his eyes with the claws, and to trust to reacting to the slightest touch, rather than to be forewarned by sight. With all his strangeness he is but a tiny beast, not more than fifteen inches in length, of which more than half is tail.

In walking, the two pairs of feet are used in very different ways. The front feet are remarkably modified, with the third toe developed at the expense of all the others, and armed with a large stout claw. The second finger has a small slender claw but the remainder do not appear above the skin. When walking on a flat surface, the two claws are bent inward and the foot rests upon a great pad of flesh, a sort of globular palm, which bulges like a boxing glove on the outer side of the hand. On a branch, however, the claws are slipped over and the branch rests in the hollow of the front, flat part of the palm, the claws forming one side, and the inner side of the boxing glove the other.

The hind feet are interesting in a wholly different fashion, but even more efficient as organs of climbing. Their grip is chameleon-like, zygodactyl, the sole being much extended heelwards, and very mobile, so that any irregularity is seized, chameleon wise, with the four nearly equal claws grasping one side and the pliant, muscular sole and heel, the other. The great sole cushion is supported by an exaggerated heel bone, and a large, made-to-order, sesamoid ossicle.

The ant-eater depends almost exclusively on the grip of the hind feet and tail, seldom releasing more than one at a time. These have such power that, without effort he can rise slowly to full height, or lean sideways almost horizontally from the branch with no other support.

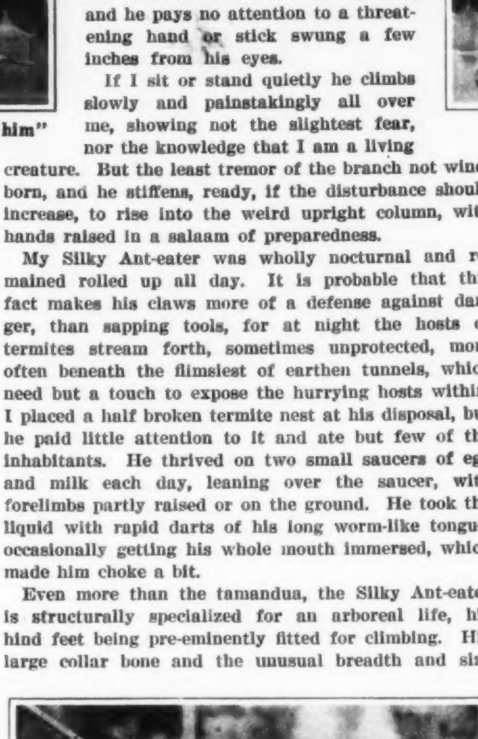
All his movements are slow and deliberate. He engenders a feeling of unusual strength, perfect balance and sureness of foothold. When walking slowly down one branch, if he can reach even a single leaf of another, he clasps it firmly and draws it toward him; then carefully steps, one foot at a time upon it keeping his tail hold until the last. No matter how much he is teased or annoyed or shaken, or left alone, no sound, not even sigh or hiss escapes him.

His strange appearance and posturing have caused many strange legends to arise among the natives, one of which is that he is the author of the caprimulgine cry which echoes through the jungles at night, like the cry of a lost soul—Poor-me-one-oh-oh. His senses seem extremely dull, and he pays no attention to a threatening hand or stick swung a few inches from his eyes.

If I sit or stand quietly he climbs slowly and painstakingly all over me, showing not the slightest fear, nor the knowledge that I am a living creature. But the least tremor of the branch not windborn, and he stiffens, ready, if the disturbance should increase, to rise into the weird upright column, with hands raised in a salaam of preparedness.

My Silky Ant-eater was wholly nocturnal and remained rolled up all day. It is probable that this fact makes his claws more of a defense against danger, than sapping tools, for at night the hosts of termites stream forth, sometimes unprotected, more often beneath the flimsiest of earthen tunnels, which need but a touch to expose the hurrying hosts within. I placed a half broken termite nest at his disposal, but he paid little attention to it and ate but few of the inhabitants. He thrived on two small saucers of egg and milk each day, leaning over the saucer, with forelimbs partly raised or on the ground. He took the liquid with rapid darts of his long worm-like tongue, occasionally getting his whole mouth immersed, which made him choke a bit.

Even more than the tamandua, the Silky Ant-eater is structurally specialized for an arboreal life, his hind feet being pre-eminently fitted for climbing. His large collar bone and the unusual breadth and size

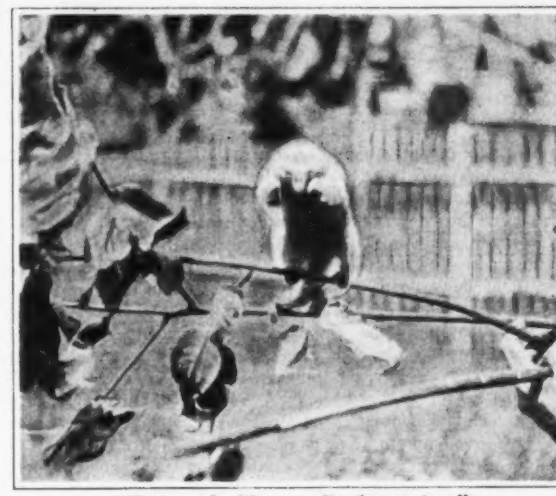


"He engenders a feeling of perfect balance and sureness of foothold"

of his ribs emphasize his arboreal character. But he is quite at home on the ground, even more so than his near relative. Once my specimen escaped from his box and walked easily and with considerable speed around five rooms looking for an exit to the jungle. At last we found and rounded him up as he was making for the open door.

The written accounts of this creature show almost a total ignorance of his actions in life. Illustrations which show him upside down, slothlike, and with a short rounded snout are wholly at fault. He never suffers the inverted position for a longer time than it takes to clamber topside again. As to his snout, it is quite long and slender, with a curious Roman break in it, which with his usual half-shut eyes conveyed an air of peevish aloofness which was very characteristic and amusing.

When given the run of a large packing case, he was constantly making his way over the branches and twigs, occasionally taking a few laps at his milk and egg. When the first hint of dawn appeared, he chose a small calibered crotch, or the crossing place of two twigs, secured a firm grip with both hind feet, one



"He turned with a supplicating gesture"

facing front, the other backward, bowed into a perfect sphere, and gave himself up to the luxury of Cyclopean day-dreams.

How Fishes Were Named

While their cry or note has suggested names for many of the birds, fishes are mute creatures, and their names are unconnected with any sound. They are named mostly from some peculiarity of appearance in shape, color, or other physical feature; or from some characteristic movement, habit, or disposition.

The whale is the "monster" fish; the walrus (an amphibian) is the whale-horse, and the narwhal the "corpse" whale (*nar*, a dead body), from its pallid appearance. The shark is the "searcher," or prowler for food, from its voracity (Fr. *chercher.*) The tunny is the "rusher" or darter, well known in Mediterranean waters (Gr. *thunos*). The grampus is the great fish (*grandis piscis*); the octopus the eight-footer; and the porpoise the pork or pig fish, from its fat appearance. The salmon is the jumper (*salio*, I leap); and the grayling is the little gray fish of the salmon kind. The trout is the nibbler; the pike is the picker, from its sharp-pointed jaws; and the crab is the scratcher, from its claws. The hake is the hooked fish, from the shape of its under jaw. The cod is the pillow fish, from its rounded shape; the turbot, from its rhomboidal spindle shape, is so named from *turbo*, a spindle; the plaice is the flat fish (*platus*); the sole is so called from its resemblance to the flat of the foot; the skate is probably the squat fish; and the mackerel the spotted fish (*macula*, a spot). The flounder, so called from flouncing and splashing about, may bear a name imitative of sound, but more probably descriptive of movement.

The perch is the speckled and mottled fish; the char, from its red belly (Gaelic *cear*, blood), is more distinctively named from its colour; and the John Dory is, of course, *jaune dorée*, the yellow-gold fish. The barbel is named from its beard, four barbules hanging from its mouth. The gudgeon and goby are said to have a stupid habit of being easily caught; perhaps the stupidity shows as much in the gaping mouth and glaring eyes, as of a baby! The ling is simply the long fish. The herring is said to be named from its gregariousness (*here*, a host), but the derivation is fanciful. The crayfish is the same in origin as the crab. The oyster is so called from its bony shell—in Greek, *osteon*, a bone. The whelk or wilk is named from its convoluted shell (*helix*, a twist or spiral). The lobster is named from the locust, which it is supposed to resemble. The mussel is sometimes mysteriously connected with the mouse—slow-moving. The halibut is the holy "butt" (*i. e.*, plaice), being good eating for holidays. Eel is probably an imitative word caught from the slimy appearance and sinuous movement of the fish. The origin of haddock, pilchard, parr, and cuttle has not been ascertained, or even ventured for.—J. L. R., in the *Scotsman.*

Twilight Phenomena

In a paper in *Archives des Sciences* P. Gruner gives a detailed *resume* of observations made in Switzerland of morning and evening sky-colors. A theory is put forward to account for the production of the effects, which depends upon diffuse reflection of light from a layer of discontinuity such as the stratosphere. It is considered that diffraction alone is insufficient to account for the phenomena, but that the diffraction effects are second in importance to those of diffuse reflection.

The Ferro-Alloys*

A Brief Description of Their Manufacture, Properties and Uses

By J. W. Richards[1]

A LARGE industry has grown up within the last fifty years, most of it within the last twenty-five years, which furnishes to steel makers alloys of iron with some of the rarer metals, in order to introduce these rare metals into steel. Such alloys are known as ferro-alloys, because they all contain iron (ferrum); some of them, however, contain more of the rare metal than iron. They were originally made in crucibles, cupolas or blast-furnaces, but are now made principally in electric furnaces, and their manufacture is one of the principal electric-furnace industries.

They are of great importance to the steel industry. The steel maker uses them for one of two purposes: (1) As reagents to take oxygen out of melted steel and thus insure sound solid casting (ferromanganese, ferrosilicon, ferroaluminium); or (2) to put into the steel a small or large percentage of the rare metal (ferromanganese, ferrochromium, ferrotungsten, ferromolybdenum, ferrovanadium, ferrotitanium, ferrouranium, ferroboron).

Let us discuss briefly these two uses. Melted steel, just before taking from the furnace, always contains some oxygen dissolved in it (like the dissolved gas in charged soda water). If this is not removed, the casting made is more or less unsound from cavities or blowholes. The addition of a small amount of a metal with a high affinity for oxygen removes this element and makes the casting sound. Manganese (1 per cent. or less) is the cheapest and most generally used reagent for accomplishing this; silicon (½ per cent. or less) is more powerful but also more expensive, and is often used to supplement the action of manganese; aluminium (0.1 per cent. or less) is still more powerful and still more expensive, and is used in very small quantities as a final addition to complete the action of the manganese and silicon. All steel makers use one, two or all three of these reagents; manganese and silicon in the form of ferro-alloys, aluminium more often as the pure metal, but ferro-aluminium is sometimes used.

The second use is to make special steels, that is, steels containing such quantities of the rare metal as give to them properties different from plain carbon steels deoxidized by manganese, silicon or aluminium. Thus we may make manganese steel by putting in 12 to 14 per cent. of manganese, making a very tough, hard steel such as is used in mining and grinding machinery, burglar-proof vaults, etc.; chromium (2 to 4 per cent) makes a very hard tool steel; tungsten (15 to 25 per cent) makes high-speed tool steel, which cuts iron while red-hot; molybdenum (6 to 10 per cent) has powers similar to tungsten, and is also used in steel for lining large guns. Vanadium (1/10 to ½ per cent.) makes very strong steel which resists shock extremely well, as when used for automobile axles; titanium, uranium and boron impart valuable properties not so easily described. Every one of these materials is used for producing some specific result which is not produced by any other; sometimes combinations of two, three or four are used in one steel, producing a particular combination of special properties for some special purpose. Some of these materials cost $5 per pound, and the special steels produced cost up to $2.50 per pound, but their particularly valuable properties justify the expense. The value of these special steels to the industries, and particularly for military purposes, is very great, so great that the supply of ferro-alloys for their manufacture is an important factor in winning the war.

FERROMANGANESE.

This is the oldest of the ferro-alloys. Its manufacture was begun about 50 years ago. It was first made in crucibles, has for a long time been made in blast-furnaces, but is now being produced in many places in electric furnaces. It is made with 30 to 85 per cent. manganese, 3 to 5 per cent. carbon, a little silicon and the rest iron. The rich grades, 75 to 85 per cent., are preferred by the steel maker, but they require rich manganese ores for their manufacture. The United States has very little rich manganese ore, but large quantities of low-grade ores; one of the present burdens of the steel maker is to use low-grade ferromanganese, in order that we may not have to use ships for importing the high-grade ores from Brazil.

The usual manufacture in blast-furnaces is wasteful of both fuel and manganese; the furnace must be run hot and slowly, with very hot blast in order to reduce the manganese oxide ore as completely as possible and not waste manganese in the slag. Yet, in spite of all efforts, from 15 to 25 per cent. of the manganese going into the furnace escapes reduction and is lost in the slag. This waste of fuel and manganese has led to the use of the electric furnace, in which fuel is required only as a chemical reagent and not to produce heat, thus saving about two-thirds the fuel requirements of the blast furnace, while the higher temperature available causes the extraction of manganese to reach 90 per cent., i. e., slag losses to be down to 10 per cent. or less. Against these economies must be set the considerable expense for electric power and the smaller scale on which the furnaces run. At the present high prices of coke and manganese ore, and in view of the scarcity of manganese and the high price of ferromanganese, the electric ferromanganese industry is able to exist and make large profits. Whether it can do so when normal conditions return, after the war, is questionable; it is to be hoped that it will be able to do so, because of the economy which it undoubtedly possesses in regard to fuel and manganese.

Steel producers use ferromanganese particularly for making the low carbon or soft steels, because they can thus introduce the required manganese for deoxidation without putting in considerable carbon. For higher carbon steels spiegeleisen (15 to 20 per cent. manganese), a cheap blast-furnace alloy, can be used, and is being used at present wherever practicable, in order to save ferromanganese. The best practice with either spiegeleisen or ferromanganese is to melt them in a small electric furnace, and tap from it the required weight to be added to the heat of steel. The melted alloy mixes quicker with and reacts more actively upon the melted steel, while less of it is necessary because less is oxidized by the furnace gases. The saving in manganese by the use of the electrically-melted ferro is alone sufficient to justify the expense of melting it in an electric furnace, while better and more homogeneous steel is produced.

FERROSILICON.

This alloy may run 15 to 90 per cent. silicon, but the most commonly used is the 50 per cent. grade. It is made from ordinary silica (quartz or sand), reduced by carbon in the presence of iron ore or scrap iron. The blast furnace is able to make only the lowest (15 per cent.) grade, because silica is exceptionally difficult to reduce, and under conditions which would reduce 99 per cent. of the iron ore in a furnace, or 75 per cent. of the manganese ore, only 15 to 20 per cent. of the silica present can be reduced, and only a low-grade silicon alloy produced. The higher grades must all be produced in the electric furnace.

The raw materials are ordinary silica, the most abundant metallic oxide on the earth's surface, iron ore or scrap iron (iron or steel turnings or punchings), and coke. Electric furnaces up to 10,000 hp. have been operated on ferrosilicon (50 per cent. grade). At the high temperature required, a not inconsiderable proportion of the reduced silicon vaporizes, and burns outside the furnace to a white silica smoke. This can be largely prevented by skillful furnace supervision. In normal times, the 50 per cent. alloy sells at $45 to $50 per ton, which is a low price for an alloy so difficult to produce.

Steel producers use ferrosilicon principally for the great activity with which the silicon removes dissolved oxygen from the steel. It is about four times as active as manganese in thus reducing blow-holes and producing sound castings. It is usual, however, to use manganese first, to do the bulk of the deoxidation, and silicon afterwards to finish up the reaction more completely. It is particularly useful in making sound steel castings which are cast into their ultimate form and do not have to be worked into shape, because a slight excess of silicon may make the steel hard to forge or roll, whereas an excess of manganese does not have so bad an effect on the working qualities. A particular kind of steel called silicon steel carries 1 to 2 per cent. of silicon and yet forges well; this would be classed as a special steel.

The ferrosilicon industry has attained large proportions in countries where electric power is cheap, particularly therefore in Switzerland, the French Alps, Norway, Canada, and parts of the United States. Under present conditions it is even profitably run where electric power is relatively dear, as at Anniston, Ala., and Baltimore, Md. It is a large, interesting, and rapidly growing industry.

FERRO-ALUMINIUM.

This alloy, with 10 to 20 per cent. of aluminium, was made in the electric furnace and used in considerable quantity in steel about 1885-88, but was displaced by pure aluminium as the latter became cheaper. Aluminium is about seven times as powerful as silicon and twenty-eight times as strong as manganese in acting upon the oxygen dissolved in steel; therefore only minute quantities are necessary, say one ounce up to a maximum of one pound of aluminium per ton of steel. Its use gives the finishing touch to the deoxidation of the steel.

About 1885 the Cowles brothers, operating the first large electrical furnaces run in America, at Lockport, New York, made and sold considerable quantities of ferroaluminium, selling the aluminium in it at the rate of about $2 per pound, while the pure metal was then costing $5. When, a few years later, pure aluminium sold for 50 cents per pound, the steel makers turned to using the pure metal instead of ferroaluminium, and at the present time aluminium is so used in practically every steel works in the world.

There seems to me a distinct opportunity for makers of ferro-alloys to revive the manufacture and sale of ferroaluminium. Such great advances have been made in the construction and operation of large electric furnaces since 1890, and so much experience has been had in reducing the difficult oxides to ferro-alloys, that the production of 50 per cent. ferroaluminium at say $100 per ton may be a distinct electric furnace possibility. That would furnish the contained aluminium at about 10 cents per pound, as against 30 cents for the commercial aluminium now used. The alloy should be broken up small before using, and thrown in the runner or on the bottom of the ladle, in order that the melted steel may quickly dissolve it as it runs into the ladle.

Such ferroaluminium would require bauxite with iron ore or scrap iron, for its manufacture, but there are large deposits of low-grade bauxite rich in iron, in Southern France, which could be reduced directly to the alloy without any additions, and thus furnish very cheap raw material for the operation.

In conclusion, ferroaluminium is not now being made, but its electric furnace production is a real possibility.

FERROCHROMIUM.

Ferrochromium is used for making what is familiarly but erroneously called "chrome steel." It makes steel exceedingly hard. Very hard cutting tools, and armor plates to resist projectiles, are made of it. Only 2 to 4 per cent. of chromium may be used.

Several grades are made in the electric furnace, depending on the per cent. of chromium (25 to 75), and the content of carbon (2 to 8 per cent.). This alloy takes up carbon so actively in the furnace that it has to be treated subsequently to remove the carbon down to what can be endured by the steel into which it is introduced.

The raw material for its manufacture is chromite, an oxide ore of both chromium and iron. If this is mixed with carbon and smelted in the electric furnace it reduces directly to ferrochromium alloy (often misnamed "ferro-chrome"), and highly saturated with carbon (6 to 10 per cent.). Steel makers want lower carbon than this, so the alloy is re-melted with more chromite in another furnace, and the excess of carbon oxidized out. The low-carbon alloy sells for 2 to 3 times the price of the high-carbon crude material.

The cutting off of importations of high-grade chromite ore from Asia Minor has led to intense prospecting in the United States. Fair material has been found in many places, and at present our country is nearly independent of foreign sources of the ore.

FERROTUNGSTEN

Tungsten (also called wolfram) imparts curious and valuable properties to steel. A small amount (2 to 5 per cent.) has been used for half a century or more, to make the steel self-hardening; that is, a tool of this steel need only be let cool in the air, and it becomes hard without the ordinary quenching or chilling operation. Larger proportions (10 to 25 per cent.) make a steel which stays hard even when red hot. A tool of this material can be run so fast on a lathe, for instance,

*A paper read at the Fourth National Exposition of Chemical Industries, New York. Reproduced from *Chem. and Met. Eng.*

[1]Professor of Metallurgy, Lehigh University; Secretary, American Electrochemical Society; Member, U. S. Naval Consulting Board.

that it gets red-hot from the friction and work, yet keeps hard and keeps on cutting. It is called high-speed tool steel, and its use alone has more than doubled the output capacity of the machine shops of the world.

The ore is used in either wolframite, a black oxide of iron and tungsten, or scheelite, a white oxide of calcium and tungsten. It is found in considerable quantities in Colorado, and some other Western States, and imports of this ore have not been necessary during the war. In this respect we are much more favorably situated than the European nations. A plentiful supply of tungsten ore may indeed be regarded as a large factor in the production of cannon and fire-arms and all kinds of machinery, and therefore a considerable factor in winning the war.

FERROMOLYBDENUM.

Molybdenum has only recently come into large use in steel. Its action being somewhat similar to that of tungsten, scarcity of the latter metal, particularly in Europe, has led to the manufacture of ferromolybdenum on a comparatively large scale.

The ores are widely distributed but not very plentiful. Molybdenum sulphide, molybdenite, looks almost exactly like shiny graphite but it is a shade lighter in color and nearly twice as heavy. It occurs usually as flakes in granite rock and might easily be mistaken for graphite. Lead molybdate, wulfenite, is a compound of lead and molybdenum oxides, a very prettily crystallized yellow to red mineral in thin square plates. It occurs abundantly in a few lead mines in the West. It is usually first treated to extract its lead, and the residue then worked for molybdenum. The sulphide used to be roasted to molybdenium oxides, on this reduced by carbon in the presence of iron ore or scrap iron in an electric furnace. It is now smelted directly in the electric furnace with carbon and a large excess of lime along with iron ore or scrap iron. Ferro with 50 to 60 per cent. of molybdenum is tapped from the furnace like other ferro-alloys, but with molybdenum up to 80 per cent. the alloy has such a high melting point that it cannot be tapped out without freezing; it is necessary to make a furnace full of this alloy and then let the furnace cool down and take it apart, taking out a large mass of solidified alloy; the furnace is then rebuilt.

The large use of molybdenum in steel has been so recent that not much has been made public about it. Rumor says that the large German guns which bombarded Liège (the "Black Berthas") were lined with molybdenum steel (6 to 7 per cent.) to increase their resistance to erosion. It seems certain that Germany drew considerable supplies of molybdenite from Norway to compensate for shortage of tungsten for high-speed tool steel. Parts of guns, gun carriages, motors, automobiles, have also been made of molybdenum steel of most excellent quality. Canada has been especially active in the manufacture of ferromolybdenum steel, most of which is exported to Europe. This alloy is therefore another valuable war material.

FERROVANADIUM.

Without vanadium the modern automobile or auto-truck would be a much weaker machine. When steel is desired to withstand the heaviest shocks and vibration, nothing is quite so effective as adding vanadium. This is another comparatively rare metal, found principally in the radium ores of Colorado and as a black sulphide on the highlands of Peru. The canary yellow Colorado ore is treated for radium, and the residues for vanadium and uranium. The U. S. Government (Bureau of Mines) operated this process for the radium supply. The black ore of Peru is rich and unusual; it is a sulphide with some asphaltic matter, and it is roasted to the condition of iron-vanadium oxide before reduction. The oxides are best reduced by metallic aluminium. This is the well-known thermit (Goldschmidt) method of reduction. Electric furnace reduction by carbon is not advantageous because of the large amount of carbon taken up by the alloy; powdered silicon is therefore put into the charge as the reducing agent, together with iron, lime and fluorspar, and then a 30 to 40 per cent. vanadium alloy is obtained with seldom over 1 per cent. of carbon, a very desirable composition (R. M. Keeney).

Only small amounts of vanadium are necessary to improve steel; 0.1 to 0.4 per cent. are the usual quantities. This is fortunate because the vanadium costs \$5 per pound and over. Metallurgists suspect that part of the improvement of the steel may be due to the vanadium combining with and removing nitrogen dissolved in the melted steel. This is probably true, yet some advantage undoubtedly must be ascribed to the final vanadium content in the steel; both avenues of improvement function. Steels thus treated are unusually resistant to shock and alternate stresses, making them very useful for axles, cranks, piston-rods, and such severe service.

FERROTITANIUM.

Titanium is an abundant element in nature. It occurs in immense amounts as a double oxide of titanium and iron, known as ilmenite, or titanic iron ore. This ore can be reduced directly by carbon in electric furnaces to ferrotitanium. The reduction proceeds easier if some aluminium is put in as a reducing agent, but this is expensive and unnecessary. The alloy running 15 to 25 per cent. titanium is sold for use in steel as a refining agent to remove oxygen and nitrogen. Thousands of tons of steel for rails have been thus treated, the tests showing considerable improvement in the mechanical properties by the use of quite small amounts (0.10 to 0.20 per cent.) of titanium.

FERROBORON.

This is another alloy whose valuable qualities have not yet been entirely determined. Boron is the metallic base of borax, which is a sodiumboron oxide. Borax is very difficult to reduce to the metallic state. Another raw material, not so abundant, is colemanite, containing lime and boron oxide. Many attempts have been made, none very successfully, to reduce this with iron oxide to ferroboron. The American Borax Co. offered a prize, for several years, for a process which would accomplish this. Boron oxide occurs rarely in nature, but it can also be manufactured from borax and colemanite. When the oxide is obtained, this can be combined with iron oxide and the resultant boron-iron compound reduced by carbon in the electric furnace to ferroboron. Small quantities of this alloy have thus been manufactured.

Experiments on steel have shown that ferroboron acts somewhat similarly to ferrovanadium. Experiments in France showed remarkably strong and tough steels were thus made, using 0.5 to 2 per cent. of boron. The results have not been properly followed up, partly on account of the difficulty in getting ferroboron; no one, as yet, has taken up its regular manufacture and steel makers can hardly be blamed in these stirring times for not having as yet thoroughly explored its possibilities as an addition to steel.

FERRO-URANIUM.

This is the latest of the ferro-alloys to enter the lists. Uranium is a very heavy and, chemically, very active element. It is found very scarcely as a black oxide, the mineral pitchblende—the mineral in which radium was first discovered. It is found more abundantly in the Colorado radium ore, a bright yellow oxide and silicate of vanadium, uranium and lime. After extracting the radium and vanadium, the uranium remains in the residue as a by-product, usually as a soda-uranium compound. This is treated so that uranium oxide is obtained, and this can be reduced by carbon in an electric furnace in the presence of iron ore or scrap iron, to ferro-uranium (30 to 60 per cent.). The recovery of uranium is not high (50 to 70 per cent.), the rest being lost in the slag. Mr. R. M. Keeney has recently described these processes in detail, for the first time in the August *Bulletin* of the American Institute of Mining Engineers.

The results of tests showing the influence of uranium on steel are not yet completely known. Some firms have claimed for it wonderful strengthening power and resistance to shock. The subject is still receiving expert attention from steel makers, and valuable results are confidently expected.

CONCLUSION.

The ferro-alloys are exceedingly important materials to the steel maker, either in the making of ordinary steel or for producing special alloy steels. They are indispensable to the steel industry. They are important factors in producing both ordinary and fine steels, and therefore in winning the war. The country well supplied with them has a great advantage over the country in which they are scarce. They are deserving of all the expert attention which they are receiving from the War Industries Board, the steel makers, and the economists. The possession by the United States of large supplies and resources in the ferro-alloy line, may be one of the important factors in determining the quick ending of the war.

Weed Destruction in Sugarcane Fields

A PROCESS of destroying weeds in canefields has been recently devised and developed by Mr. C. F. Eckart, manager of a sugar company in Hawaii, with the result that less than one-half of the labor formerly required is needed on the treated areas to bring the cane to maturity. In addition to the large saving in labor, the increased yield of cane as a result of the treatment, it is estimated, averages ten tons per acre.

Mr. Eckart found that small unexpanded cane shoots were able to penetrate a suitable paper covering placed directly on the rows of stubble immediately after harvesting, whereas the weeds are unable to penetrate it. The first step in this process is to "palepale," or free the rows of trash in the ordinary way, as soon after harvesting as possible. During this operation a point is made to cut off with the hoe any shoots which are in evidence in the cane row. The stubble rows are then fertilised, the fertiliser being distributed along the middle of the rows. Strips of tar or asphalt felt (weighing not more than 9 lb. per 100 square feet) are next placed longitudinally on the rows of stubble, so that they lie directly in surface contact with them in the form of a cover. If the field contains a fair number of stones or rocks which are conveniently at hand, these are placed along the edges of the paper strips to hold them down, and in addition the edges of the strips are also covered well with some of the dried cane leaves or trash lying in the adjacent spaces between the cane rows. It has been found that the trash is generally sufficient in itself to hold the papers in place against the tendency of the wind to lift them.

Owing to the spearlike and comparatively rigid nature of the young cane shoots, and the mechanical pressure they are able to exert when they come into contact with the paper covering, the latter is punctured and the shoots emerge. The weeds, with their relatively soft terminal points, are soon smothered out, or are dried up by the solar heat radiating from the underside of the covering.

Five or six weeks after the paper coverings have been applied, laborers pass along the cane rows, and with a knife cut longitudinal slits in the paper at such places as are under pressure from expanded shoots, these places being distinctly manifested by the tentlike elevations. The slitting is inexpensive, and costs about 35 cents an acre in practice. At first these shoots are naturally quite etiolated, but they quickly turn green and take on a vigorous growth.

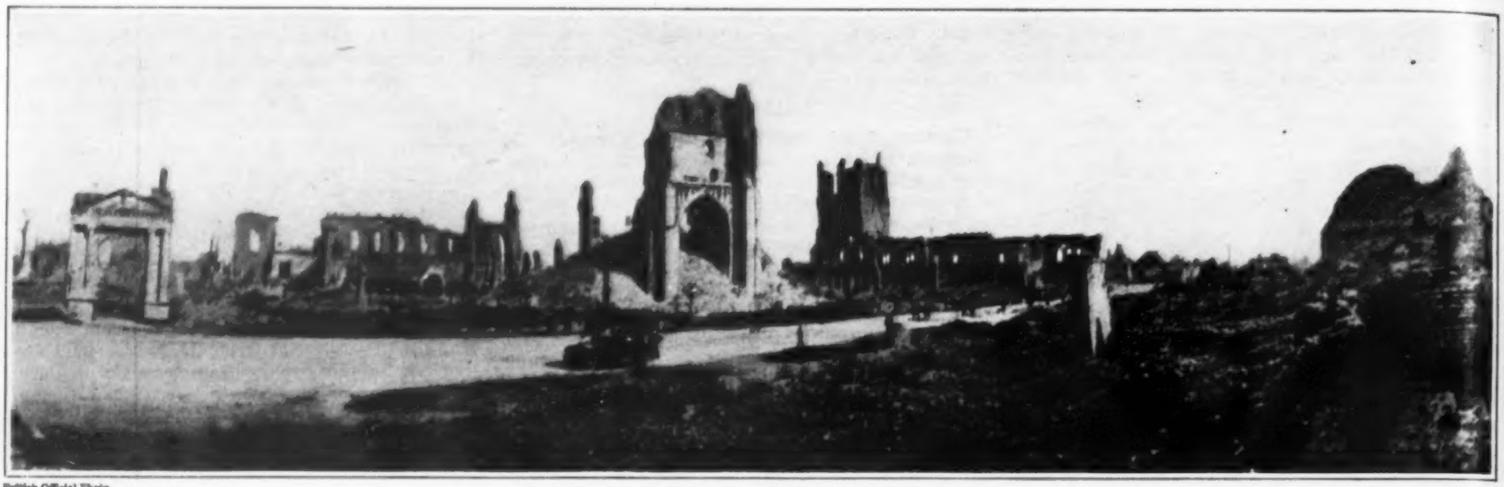
The right kind of paper must be used. Of the many papers that have been tried in this process, the best is a lightweight tar or asphalt felt. The common black sheathing felt, weighing 9 lb. to 100 square feet, is to be preferred above all others which have been tested. Possibly a lighter felt might prove even more suitable, since the 9 lb. paper is the lightest that has been tried.

The large gain in the growth of the cane in this process is due to the automatic eradication of weeds in the cane rows and to the pronounced mulching action of the paper covers. Being black and impregnated with such material as tar and asphalt, they absorb a large amount of heat, which they impart to the soil of the cane rows.—*U. S. Bureau of Commerce.*

The Influenza Epidemic

EPIDEMIC influenza, concerning which much has been written, is by no means a new or novel affliction. Its pandemic character is practically its most characteristic feature. Inasmuch as epidemics of this disease have been known since the eleventh and twelfth centuries, it is obvious that many of the modern factors to which much influence is now attributed probably play little part in its dissemination. Subways and methods of transportation, house congestion, etc., are of less consequence in all probability than a decrease of personal immunity and the violation or neglect of the general hygienic rules essential to the maintenance of individual health.

One or two items stand out most noteworthily. Influenza is constantly present in the United States, there having been 18,886 deaths from this cause in the registration area during the year 1916, while the annual average from 1906 to 1910 was 7,760. Urban congestion, contrary to general impressions, does not appear to be a dominating item in casualty. In 1900, for example, the mortality rate per 100,000 population was 24.2 for the cities in the registration States, and 29.6 in their rural sections, while in 1906, the figures were respectively 19.1 and 34.6. It may be said that mortality figures do not reflect the degree of infection of the community, but rather indicate the greater opportunities for medical attendance in urban centers as opposed to rural. This, however, is partially offset by the fact that the mortality from the disease is exceedingly low, regardless of hospital facilities, under ordinary conditions. It is only in the presence of a severe pandemic that the complicating bronchial pneumonia adds greatly to the toll, and these deaths are very largely concealed in the statistical reports under the head of "deaths from pneumonia."—*From an Editorial in American Medicine.*



British Official Photo

What the Huns did to Ypres

A Visit to the British Front in September

Condition of Cities in Northern France on Enemy's Final Retirement

By Hamilton M. Wright

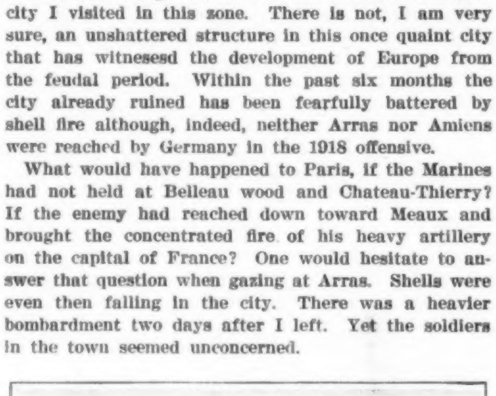
I visited Arras, Vimy Ridge, Amiens, Villers-Bretonneaux, Albert, and many other cities and regions whose names have been carried to the far corners of the world by reason of the heroic battles fought within them. I trod upon ground hallowed by the heroic sacrifice of British and French troops, who resisted the hordes of an enemy that was armed with the most barbaric and terrible means of warfare since mankind became able to leave a record of its impressions. I saw the stricken cities, the sites of vanished cities, the drear, desolated, and unhappy country embracing not hundreds of square miles but actually thousands of square miles in area left in the wake of the retreating Hun. I crossed and recrossed the part of northern France between the Hindenburg line and the line of the farthest German advance in their 1918 offensive which began on March 21 last. I saw this region not as it was six months ago, but as it is today and as it will remain until the giant problem of its reconstruction is under way.

For miles the country is a desert. There are no fences, no houses, no trees, only blasted stumps, grave yards, and shell holes. For hours one may ride along the roads through a land once beautiful and prosperous that is today a naked waste pitted with enormous shell craters and pock-marked with innumerable smaller shell holes. In some instances villages have been completely blown away leaving not even mounds of rubbish to mark their sites. In a way, this has all been told, many times. Yet I doubt if we can appreciate the measure of destruction through the bare statement that a city has vanished. Imagine a great section of the brick built suburbs of Chicago, Brooklyn or Baltimore to have vanished, leaving only the bare streets and you may picture the fury with which the stone and brick built cities of northern France have been laid waste. Sometimes I have heard people say that the blasting of material property, the destruction of cities might be forgiven, that they are not to be classed with the sinking of the Lusitania, with the murder of innocent civilians. That is the pity of it. The persons who reason thus do not know. Thousands of civilians have perished in French cities through high explosives, airplane bombs, often liberated far back of the war zone, and through gas shells, at the hands of the enemy.

There are, too, the plains, the long low rolling levels of farm lands laid waste. Voyaging upon them to Peronne, I beheld the scene of the wonderful British tank drive of August 8 last. Still upon the earth, across the first, second, third and fourth German lines were the heavy marks of the English track layers. Through the enemy's outposts and rear guards they had gone, past his front lines and resistance positions, coming upon his ranks almost as fully exposed in the trenches as if in open ditches. Ah, what a death-dealing advance those tanks made! Fancy them advancing to the crash of their light artillery, the staccato roar of their machine guns, rolling, rocking, plunging forward, filled with the smoke of their guns mingled with the odor of spent gasoline. Deathly hot and stuffy it was in those charging tanks. The enemy could not resist. They returned to their bases covered with more than dust. They had literally ground their way through the enemy and cracked his line in the center. Too, I saw some German tanks, built like fortresses, with no projecting over-hang to their chain drive. They could not climb suddenly. They could not resist the charges. One of them had found itself helpless in a little depression beside the road.

The ancient city of Arras, birthplace of Joan of Arc, has attained complete destruction. Arras was the first city I visited in this zone. There is not, I am very sure, an unshattered structure in this once quaint city that has witnesesd the development of Europe from the feudal period. Within the past six months the city already ruined has been fearfully battered by shell fire although, indeed, neither Arras nor Amiens were reached by Germany in the 1918 offensive.

What would have happened to Paris, if the Marines had not held at Belleau wood and Chateau-Thierry? If the enemy had reached down toward Meaux and brought the concentrated fire of his heavy artillery on the capital of France? One would hesitate to answer that question when gazing at Arras. Shells were even then falling in the city. There was a heavier bombardment two days after I left. Yet the soldiers in the town seemed unconcerned.



Croui Castle, near Soissons

"I'm bloomin' fed up with the bloody shells. I wouldn't turn my head around to look at them," said one.

There are 20 feet of debris on the floors of the great cathedral. The walls still stand but the roof is open to the heavens. Signs advise visitors against the removal of the relics. After the war the ruins will be permitted to remain, for a time at least, as an object lesson in German methods. The once magnificent Hotel de Ville, or City Hall, on the north side of the public square, was ruins six months ago. Today it is a great pile of bricks and dust. In September, 1916, the German advance guards held the south side of the square for 48 hours. Finding the direct fire of the British too hot for them they had worked their way underground excavating enormous caves and chambers which they employed as dressing stations for their wounded. Into one of these which was about 25 feet below the level of the square, I peered. Two tiny gleams of light came from tallow candles before a shrine. Evidently, the only spot in which worship could with safety be conducted was underground. In an early day the monks excavated an underground passage between Arras and Cambrai. Parts of this were utilized by the enemy in making the underground advance before referred to.

Across the side streets and in the suburbs of Arras are cheveaux de frieze of barbed wire and criss-cross steel "hedge hogs" that once retarded the progress of troops through the city. In some places iron palings have been cut off by shell splinters or bit and gouged by tiny particles of shrapnel, high explosive that scattered a tornado of steel. When we read in our paper over the coffee cups that a city "is removed from the range of shell fire," we will perceive in the light of understanding what that perfunctory military phrasing implies to the people who live therein.

In fairer days, Arras, on the river Scarpe, had a population of about 35,000 persons. Today it is the ruined capital of a ruined department. I understood that one old lady has lived in Arras through all its recent shelling. Formerly she was a personage of wealth and lived upon an estate in the country nearby. When her chateau was destroyed, she moved into the city, and brought with her her blooded horses and dogs. Most of her horses were killed and some of her dogs and she was reduced to poverty. Her lot, however, has been alleviated by the French Government which has granted her an annuity. At present she spends the greater part of her time in Red Cross work.

From Arras on the Vimy ridge through a deserted land, past endless rows of empty trenches we went, past innumerable dug-outs built into the hill sides, giant artillery emplacements, dismantled wagons, and many graves and graveyards. Some of the cemeteries where French soldiers are buried passed into German hands and in these the Germans, too, buried their dead. But it is hardly to be thought, in the light of the universally bitter feeling against the enemy, that the graves will be allowed to remain thus unseparated.

Vimy ridge itself, a sponge of human blood, is a long, low, treeless mound. It is two or three hundred feet high and perhaps ten or twelve miles long. Weeds have overgrown the ridge. Rushes line the innumerable shell holes that have become a thousand little lakes filled with croaking frogs. From this monotony rises the crucifix to the Canadians—the 50,000 who went down in a day. Strange the boche had not bombed it. From the ridge we overlooked the smouldering, gas-ridden city of Lens. It was still under fire. Lens was within the British lines although it had not been thoroughly "mopped up." From the shelter of the ridge and over our heads shells were hissing toward the enemy. Vimy ridge, too, would soon say its last goodby to war. On the plains below enemy shells were bursting. From our vantage point I could make out several dots moving toward us from the trenches. They became larger. They were sinewy, lithe Australian lads who moved in quick short steps.

"Good leather," said they by way of greeting. "What's the news from the other fronts?"

"And that is what they all ask," observed the Major, as the boys trailed over the bow of Vimy ridge. "Some of our men have been fighting for months, even for years, in the same region. War for them is steady day's work."

Scatter a billion dollars worth of high explosive in

British Official Photo

Cathedral of Peronne as it now appears

British Official Photo

Albert Cathedral as the Germans left it

the industrial suburbs of Pittsburgh, touch it off and the result will give a fair sample of what this once vast coal center in northern France looks like. The long rows of brick tenements, the brick cottages, in which lived workman and coal miners, have gone. Mines have been flooded. Save for the soldiers here is an uninhabited zone. The destruction in this region, by the way, was conducted with the same spitefulness along the Aisne, and along the parts of the Marne front where I have been. One of the British officers told me that in the German advance this year the enemy threw gas shells into cities from a range of eleven miles. On a road crowded with refugees he saw a young woman following a two-wheeled cart. She was on foot and carried a baby in her arms. Her pitiable expression caused him to inquire if he could be of aid. The woman did not answer coherently. She was demented. She had been gassed. Her baby had been dead many hours from the poisonous fumes. A myriad of instances of German brutality can be authenticated. Just the other day I met an American soldier who is the victim of German spite. He slept in a bed in which gas had been released, was badly gas-burned, and sent to the hospital.

I was in Amiens, one of the first five or six centers of France, before the war, with a population of more than 100,000. The enemy did not occupy it this year. But it shows the effect of recent bombing. The great railroad station has been badly "shot up." There are forty-two jagged holes in a steel sign directing travellers to the Paris platform. The outdoor steel-enclosed lavatories have been literally sieved by stray bits of shrapnel, some so tiny as to make holes through which a pencil would scarcely pass. Any one of them would have killed a man—or a woman or a baby. I could not help wondering how the Grand Central Station at 42nd Street, New York, would have looked after such an ordeal.

Boys were selling Paris papers on the streets. Old men and old women and children were crowding into town carrying a few belongings, and great loaves of bread and bottles of wine. The Cathedral is practically undamaged, that is, there has been no direct hit upon the main building. Yet less than a block away a shell had taken off the top of a lodging house. Shrapnel splinters of this had scarred the stone walls of the Cathedral. A large department store had been gutted

French Official Photo

In the heart of Chauny

down to the basement. Only the walls stood. High above the ground a floor hung out from the ruins of an hotel, without walls and without ceiling. Upon this solitary shelf stood a bed with the disarranged bed clothing still upon it. Had some unfortunate wayfarer resting upon that couch been suddenly aroused

British Official Photo

The ruins of Albert

to consciousness by the bursting shell to find himself thus exposed to the elements?

I shall not give you an endless catalogue of destruction. Imagine for yourself this drear desert belt of France upon which the Germans this year completed their work of ruin. Save at points as Cambrai where the British held despite the preponderance of the enemy against them it will run 40 or 50 miles in width and extends the length of the British line. In this region the Germans intent on capturing the entire coal fields massed their most formidable divisions. Here in this war-scarred area, scene of a thousand battles, they brought the pressure of their numbers. But Britain held approximately two-thirds of the Western front with one-third of the Allied troops. The Prussian was not able to wrest the bone from the British bulldog.

Albert in the past few months had been reduced to a mound of bricks. Even the famous leaning Virgin on the ruins of the cathedral had been shot away. Some there were that believed that its preservation through years of warfare had been due to divine interference. There is not only no whole building in Albert. There is but one room intact in the city. In it lived a French sergeant. There was a carpet on the floor, a washstand with a china pitcher and wash basin, a white iron bed, a dresser. A plank led over a gaping cellar to the doorwoy. Over this the sergeant invited me.

"Enter, messieur, into the only room in Albert," said he, politely.

He was more fortunate than most soldiers policing destroyed cities out of the zone of fire. Often it is hard to find a shelter at all from the elements. In the French towns far back of the line I saw our American boys waiting to go forward.

"And how do you like them?" I asked the Major.

"Like them? That isn't quite the word," said he. "We honor them. We love them. They are our own people. We have found them modest and brave. They can have anything in the world that our boys have. Ah, do not think that we do not give you credit for it. It is your fresh troops that have turned the tide of war. It is your vigorous young chaps that have their knives always into him, who came into the fight, not too soon, not too late, but just at the right time, that have inspired us all with the certainty of Victory."

Reinforced Metals

To produce a reinforced copper plate, a sheet of perforated steel forms the foundation, and is covered with copper by electro-deposition. Lead can be reinforced by simple rolling into the perforations in steel sheets. Tubing can also be produced and the products used in the making of acid-resisting tanks and pipes.

British Official Photo

The city of Lens is now a desert waste

British Official Photo

What is left of Bailloul

Food Shortage and High Prices

MANY explanations have been given to account for the stringent condition of our food supply, and for the high prices that prevail, but one of the most potent reasons for the present state of affairs has apparently been entirely overlooked. This is the enormously increased purchasing power of labor. Hundreds of thousands of men who were earning $18 to $24 a week before the war are now getting from $50 to $90, and most of them are spending their earnings as fast as they get them, and a very large percentage of this money is going into food. It is but natural, therefore, that, with our home demand enormously increased in this way, in addition to the very liberal supplies required for our army and navy, as well as the great quantities furnished to our allies and many neutral nations, extreme difficulty is being experienced in meeting all demands; and as price is determined largely by demand, this has risen in proportion. The only wonder is that America has fared as well as she has.

A very serious feature of this new demand of the working man for food supplies is his extravagance. While the laboring man has as good a right to all the food he requires as anyone else, he rests under the moral obligation that involves everyone to use that food reasonably and economically; but he does neither as a rule. Take an actual example that illustrates the methods followed in the homes of too many working men, and which is really more injurious to them than to anyone else. A metal worker who formerly earned $22 a week now gets between $50 and $60. At his evening meal he now has three different kinds of meat, of which he and his small family cannot possibly consume over 40 per cent. The other 60 per cent. is wasted, because his wife does not know enough about domestic economy to utilize it; it would be too much trouble if she did—with so much money available, and then again "What would the neighbors say if they saw her using scraps?"

Another actual, and sample case, in another community is that of a mechanic whose earnings had tripled in the last two years. When his wife buys poultry, which is frequently, she gets an entire chicken for each member of the family. This enables each to pick the particular part of the bird they like best, and, naturally, the rest is wasted. With such methods in vogue in thousands of households, is it any wonder that food is scarce and prices high?

It is a customary and popular pastime to rail at the wealthy on all occasions, and this is the case at present when constant appeals are published in the daily papers demanding restrictions on extravagance in the households of the moneyed classes. But anyone who knows the actual conditions realizes the practical impossibility of accomplishing anything in this direction. Competent servants are scarce, and as their services are in constant demand they will not stay in a household where they are not permitted to do absolutely as they please, and economy does not fit in with their ideas, when someone else pays the bills; and here again we find the working people ultimately responsible for needless waste. It is one of the advantages of wealth that it is able to hire someone else to undertake the drudgery of housework; and it is one of the penalties that to retain these workers it must surrender itself into their irresponsible hands.

In the last analysis the problem of food conservation seems to come down to a question of individual frugality, the lack of which causes much of the poverty and misery of the world; and to increase this some means must be devised to encourage and increase thrift in the masses, and to teach them that poverty and suffering are largely the result of self-indulgence and a desire to outdo their neighbors.

A most serious feature of the present situation will be the condition and the feelings of these thoughtless and improvident people when war work ends, and with it the necessity of paying any price to get it accomplished quickly, and when a million workers, now in the armies in France, return to take up their former life at home, with the consequent depression in wages, notwithstanding the probability of commercial activity for some years to come. In that time will the hosts of ignorant laborers, who are now getting fabulous wages, quietly accept a return to the old scale?

The Animus of German Scientific Men

A CORRESPONDENT of *Nature*, in speaking of the future treatment of German scientific men by those in other countries, makes the following pertinent remarks:

"I have not heard of a single letter from the very large number of the scientific classes in Germany to acquaintances in this counrty in which such acts have been denounced, nor have I seen any protest or condemnation of German methods coming from the Germans in our midst, of whom there are many who have enjoyed in this country friendship, hospitality, and even protection, such as no British subject could hope to receive in Germany. Any expressions of this kind would be well known, quoted, and notorious.

"Instead of protecting objects of science and art by leaving them intact for the benefit of other nations and the world in general, the German has raised looting and destruction into a devilish art. Soldiers are trained, and even the officers led by them, to commit useless destruction, combined with every conceivable atrocity on man, woman, and child. It is lamentable to think of the geological and natural-history collections which have been destroyed in Belgium alone—a country famous for its scientific men, the work of their lives gone forever. I trust all this will not be forgotten when the war is fought out to proper issue."

Pneumonia as a Public Health Problem*

By Rufus Cole, M.D., Rockefeller Institute Hospital

PNEUMONIA is really a public health problem, but it has not been so recognized until recently. It took the insight of Dr. Biggs to see that pneumonia might be prevented, and that the high mortality from this disease might possibly be reduced. Pneumonia causes more deaths in this country than any other of the communicable diseases. It is responsible each year for over 100,000 deaths in the United States, and for over 10,000 deaths annually in New York City alone. It is therefore obvious that it is a disease which we should study carefully, and that we should try to reduce its effect on the mortality rate if this is possible. As long as pneumonia was considered a disease arising, so to speak, from within, as long as it was considered that individuals suffering from it carried the causative organisms in their mouths before they became sick, it seemed that little could be done to prevent its spread.

Pasteur said that any bacterial disease is theoretically preventable when we know the means by which the organisms causing it gain entrance to the body. With pneumonia, it was supposed that we were dealing with a disease in which the organisms were already present in the body—a disease which originated, not because the person acquiring it received something without, but because something in the body was changed, and micro-organisms previously present but harmless were able to cause this serious infection. However, studies have shown that the organisms causing the disease are not all identical in cultural characters, but that they differ among themselves, not in morphology but in their finer biological characteristics. This, of course, becomes of extreme importance when we begin to discuss the question of prevention, to try to limit the transmission of the disease, and above all to attempt to employ specific methods of cure. It has been shown that in two-thirds of the cases of pneumonia the organisms causing the disease are acquired from without; that these organisms are not present ordinarily in the mouths of healthy persons; that they are found only in the mouths of those sick with the disease or in their immediate environment, especially in dust, or in the mouths of persons closely associated with the sick. These healthy persons or carriers, who carry these organisms are very limited in number however. They are relatively no more numerous than the healthy persons who carry diphtheria bacilli, or who carry the organisms causing meningitis. Therefore, if it is possible to limit the spread of the organisms from those sick of the disease and to destroy the organisms in the immediate environment of the patient, much will have been accomplished in limiting the occurrence of pneumonia.

A great deal has been done in preventing the spread of diseases due to organisms which inhabit the intestinal tract, but little has been done in the prevention of diseases in which the organisms leave the body through the mouth or respiratory tract. However, this has now become of great importance owing to the prevalence of pneumonia in the army during the past winter. It was expected that there would be much pneumonia among the soldiers. We thought we could estimate almost accurately the number of cases of pneumonia which would occur, but, as it happened, the very widespread occurrence of this disease could not have been foretold, because a new type developed, a type not due to the pneumoccus, which is the cause of the kind of pneumonia we speak of as "lobar," but a type due to the streptococcus, an entirely different organism. This kind of pneumonia is not a new disease in the proper sense of the term, but its occurrence in adults in epidemic form is new to most of us. The way in which it has spread has been most interesting. Of course, we do not know the details accurately, but taking all the knowledge we have on the subject into consideration, it seems that the epidemic occurred because certain organisms, which are occasionally present in the mouths of normal individuals and are then of slight virulence, became more and more virulent. This increase in virulence of the bacteria occurred because they grew on soil which was especially suited to their growth, and this favorable soil was furnished by the presence of measles infection. These organisms were spread widely among the soldiers, causing much pneumonia and many deaths, even in those not suffering from measles. This form of pneumonia has now even appeared among the civilian population, so that this disease is now not only to be reckoned with as an army disease, but it must also be seriously considered by those entrusted with the health of the civilian population, and great efforts must be made to prevent its spread.

The place where the infectious organisms are most concentrated is in the respiratory tract of the patient. That is where we can attack them most successfully. It is important in the first place to prevent the infection spreading from the individual sick with the disease. This can be done, first, by isolation of the patient. This means that we must recognize that these respiratory diseases are communicable. Second, we can prevent the spread of the infection by cleanliness in the surroundings of the patient. It has long been known that the organisms causing pneumonia may exist for a considerable time in dust. They are spread from the patient sick of the pneumonia to the dust around him, and this dust is most infectious. By preventing the spread of this dust undoubtedly much can be done. The question of dust infection has not been given sufficient attention by those engaged in public health work. For years Dr. Prudden has been impressing upon us the dangers of dust infection, but we have been so interested in better water supplies, better sewerage systems, etc., that we have forgotten the importance of dust in spreading infection, especially in spreading the acute respiratory diseases, which now cause more deaths than all the other acute communicable diseases combined.

It is possible that by the use of gauze masks much can be accomplished in preventing the transmission of infection from the mouths of persons sick with the disease. Last week, in visiting a camp in Illinois, it was interesting to see that every patient suffering from an acute infection of the respiratory tract wore a mask constantly when he was not confined to his bed. The patient's bed was surrounded by sheets hung from wires to prevent droplets of saliva containing the infectious agent from being carried to the patients in adjoining beds. Just how effective masks are in preventing the spread of infection is not yet certain. Their use, however, does emphasize to all the personnel in the hospital, to the nurses and in the household, to the members of the family surrounding the pneumonia patient, that they are dealing with a communicable disease, and that this disease is spread by coughing, spitting, etc.

A very important measure to be taken by public health authorities consists in making the disease reportable, because in the history of the prevention of all infectious diseases this has been found to be the most important initial measure. After this, isolation and the institution of measures for preventing the spread of the infection from the patient, such as those just mentioned, must be insisted upon.

There is a still further method, a more simple one, which it is conceivable might be effective. It is the method of vaccination which has been so useful in preventing the spread of typhoid fever among the soldiers. Colonel Russell, who has been largely responsible for its introduction in the American army, has said that, judging from the Spanish American War, if we had not employed this method of prevention we should already have had upward of 200,000 cases of typhoid fever with a corresponding number of deaths. The use of this method in preventing pneumonia is still in an experimental stage. As has been said, as far as two-thirds of the cases of pnuemonia are concerned the organisms causing the disease are specific, they are acquired by the patient by transmission from without; therefore, if a method of inducing immunity to this type of infection by means of vaccination could be developed it is certain that a large number of the cases of the disease due to pneumococci might be prevented. This method has been tried to some extent in South Africa, where pneumonia has existed to a very wide extent among the workers in the mines, and where it has caused great economic loss.

During the past winter 12,000 of our soldiers at Camp Upton were inoculated with antipneumococcus vaccine.

*Read at Annual Conference of Health Officers at Saratoga Springs.—*The Health News.*

Before these soldiers left for France, which was several months following the inoculation, not a case of pneumonia due to the types of organism used for inoculation developed, while among the men not so inoculated there occurred a considerable number of cases. The method therefore seems most promising. It will probably be extensively tested during the coming winter, and we hope its use will result in very materially reducing the number of cases of pneumonia in the army. This method, however, is hardly applicable to civil life except in cases where large numbers of men are grouped together and where the danger of infection exists to a very marked and dangerous degree.

The method of treatment of cases of pneumonia by means of immune serum is at present applicable in only one type of the disease. This type of infection, however, is responsible for at least one-third of the cases ending fatally; it is responsible for more deaths than occur from meningitis, typhoid fever, diphtheria, and scarlet fever combined. It is therefore of great importance that this serum should be employed in suitable cases and that efforts should be made to administer it in the best possible way. The technique of determining which are the suitable cases and the technique of administration are not easy. Because of these difficulties, which stand in the way of the general practitioner carrying out this form of treatment successfully, efforts have been made in this and certain other States to develop an organization within the health department which may be of assistance to the physicians in the diagnosis and serum treatment of this disease. New York is the first State in which this has been put into successful operation.

If Lord Lister could have foreseen the difficulties in operation of the methods which were necessary for the prevention of the infectious surgical diseases, such as hospital gangrene, erysipelas, wound infection, etc., which formerly caused such a large number of deaths among the surgical cases in hospitals, it is probable that he would never have had the temerity to continue his efforts to attempt to bring about the elimination of these diseases. It has required the building of great new operating rooms and sterilizing plants, and the development of specially trained groups of physicians and of nurses and assistants. But the results have been well worth the effort.

To stop or even diminish the mortality from pneumonia is worth almost any degree of effort, however great. Dr. Biggs and all who comprise the Department of Health of this State have shown great courage in attempting to lessen the mortality from this disease. It is not an impossible task. More and more is constantly being learned concerning the nature of the disease, and with increasing knowledge the application of methods of prevention as well as those of treatment will become more simple and less difficult. Possibly not all of the one or two points of reduction in the annual mortality rate for which Dr. Biggs hopes, can be realized by lessening the mortality from pneumonia, but we hope that a considerable proportion of this reduction may result from the antipneumonia campaign.

Scientific Plant Breeding

So much attention has been directed to the purely scientific advance that has followed the birth of Genetics as a new branch of science that little regard has been paid to the very remarkable results already reached by the application of Mendelian methods to the problems of economic plant production. It is necessary to distinguish somewhat sharply between the facts which Mendel was the first to discover, and the hypotheses which have been put forward to explain these facts. The practical plant breeder is not primarily concerned with the theory of the subject; the Mendelian fact of grand importance to him is that unit characters do segregate, and that new combinations of these characters can be made.

It may be of interest, therefore, to consider some of the more important results obtained in regard to food-producing plants, and to indicate some of the difficulties which may impede future progress. Of food grains none is more important than wheat. The most marked achievement in wheat breeding is the production of a variety resistant, if not entirely immune, to the fungous disease known as Yellow Rust *(Puccinia glumarum)*, as a result of the discovery that resistance to this disease obeys the Mendelian law of segregation. Once this was established it became a comparatively simple matter to transfer this character as an independent unit from the poor yielding Russian wheat, "Ghirka," in which it was found, to a wheat suitable to the conditions of England.

The possible economic value of this achievement becomes apparent if the enormous yearly losses caused by rust—perhaps not far short of 10 per cent. of the yield annually—are considered. Another economic character that can be controlled in the same way is stiffness of straw, a matter of importance in those parts of the country, such as the Fens, where a weak-strawed wheat becomes "laid" in wet seasons. It is interesting to learn that a short, stiff-strawed variety known as "Fenuan" has recently been produced which is likely to be largely adopted in the Fen country. But the possibility of greater additions to the food supply of the country is now in sight. It is well known that wheat is commonly a slow-growing plant; sown in late autumn or winter, it is harvested in August. Barley and oats, on the other hand, come to maturity more rapidly, and need not be sown until spring. There are, however, certain varieties of wheat which can be sown in spring, but, unfortunately, their yield of grain is considerably less than that given by winter wheats. The result has been that under the ordinary conditions of farming in this country the area that can be sown with wheat is limited to that not occupied by a crop during winter. Barley and oats must be grown after "roots" because the latter are not completely off the ground until early spring. If, then, it were possible to make a spring wheat combining the character of early maturity with a yield approaching that given by winter wheat, the economic gain might be enormous, for, obviously it would be in the interest of home food production to curtail the area occupied annually by barley. If, then, we could add to the existing acreage sown annually with wheat only one-quarter of the normal acreage under barley and oats, we should add probably 20 per cent. to the home-grown cereals available for human food. The possibility of making an improved spring wheat depends upon how far early maturity and yielding capacity are found to segregate. Apparently, there are indications that the former does, but the problem in regard to the latter is complex, depending for its solution on the clearing up of the difficulties that are encountered in dealing with quantitative characters, such as yield, as distinct from qualitative characters, such as color of grain.

The questions involved are obviously of great economic importance, for it is the quantitative characters that often determine the economic value of a plant or animal. But it is not simply a question of the universality of the Mendelian law. If, as some geneticists hold, the inheritance of quantitative characters is regulated by a complex of unit characters, the practical application of Mendelian principles becomes exceedingly difficult, for with any number of characters over three the number of possible combinations of unit characters becomes generally too large to handle. And the difficulty does not end there, for, owing to environmental fluctuation, the comparative genetic behavior of individuals cannot be disentangled, and the plant breeder is consequently driven to resort to purely empirical methods of selection. Nevertheless, the fact that the exact nature of the laws regulating the inheritance of quantitative characters is still obscure may not seriously impede the work of the practical breeder. In fact, it has been found in practice that, provided desirable qualitative characters can be built up in the desired complex, the quantitative characters may be susceptible of improvement by selective methods of a more or less empirical nature.

But when all is said, scientific plant improvement in Great Britain has made only a small beginning, due, no doubt, in part to the general excellence of the varieties of economic plants now established in this country. The "Improvers" of agriculture and horticulture in the nineteenth century revolutionised the industry, and, as an outcome of their activities and influence, British seedsmen, largely by selective methods, effected very great improvements in economic plants. It is only comparatively recently that this country has fallen behind. Allusion may be made to the great advances achieved in Sweeden as a result of the work of the Svälof plant-breeding station. Denmark also is forging ahead, but, curiously enough, progress has not been remarkable in Germany, owing perhaps, to the extraordinary cult of Darwinism which prevails there, and the consequent belief in the effectiveness of mass selection. In America considerable progress has been made from a scientific as well as from an economic point of view—notably in producing a cotton immune to the destructive Wilt disease.

But if a striking object-lesson of the successful application of new methods to plant production is needed we must turn to India.[1] Dating from the foundation of the Pusa Research Institute about the beginning of the present century, great developments in the scientific exploitation of Indian agriculture have taken place. Much credit is due to Lord Curzon, who, aided, it is now curious to recall, by the munificent bequest of an American (Mr. Phipps), founded a department which it is no exaggeration to say has added thousands, and will add millions, to the wealth of the country. India undoubtedly presented a fine field for the modern plant breeder. If we consider the immense variety of her plant products, their value either as food or in the arts and industries, and then observe that, owing to the absence of any skilled seed production industry, there is an uncounted number of identifiable races within each distinctive variety of economic plant, we can form some conception of the possibilities which even selection presents: superadding hybridisation, it is difficult to assign any limits to the field that is opening out.

It would be impossible in the ordinary limits of space to give a detailed account of what has already been achieved, but some indication may be given of proved successes in relation to the more important economic plants.

Mention may first be made of Wheat, of which upwards of 30 million acres are grown, and which was naturally one of the first crops to receive attention. Both selection and hybridisation have been brought into action, and several new varieties are now firmly established. In the United Provinces in 1917 alone "Pusa No. 12" occupied 100,000 acres, and was extensively grown in the Punjab as well. This wheat gives a cultivator an *increased yield of 25 per cent.* over the varieties formerly grown by him, as well as nearly one shilling per quarter more on the market, owing to its improved quality. Another and later production of Pusa has on occasions given a yield of nearly fifty-five bushels per acre, which for India is an unheard-of figure, and may be compared with thirty-two bushels, the British average yield of wheat. In the Punjab another new variety occupied 97,000 acres, and it is estimated that the growers of this wheat were presented with an additional income of nearly 15,000*l.* In the Central Provinces improved varieties, returning to the cultivators considerably increased profits, occupied 200,000 acres.

Remarkable progress is also being made in the production of improved varieties of rice, the most important cereal crop in India. A variety known as "Indrasail," isolated by pure line selection, occupied 20,000 acres in Bengal. In the Central Provinces it has been necessary to establish thirty seed farms for the production of other new varieties. Turning to non-food products, we find that extraordinary advances have been made in regard to cotton (of which 20 million acres are grown in India). In Surat an improved cotton has been produced giving a premium value of 13 per cent.; in Sind new varieties are giving a premium of 23 per cent. In the Central Provinces a new introduction is estimated to occupy no less than 800,000 acres, and to have brought the cultivators increased profits of nearly 900,000*l.* After this we may pass over such relatively inconsiderable figures as 215,000 acres under a new variety in the Punjab, but, for its human interest, mention may be made of one incident in a campaign directed to the eradication from a certain district of an inferior indigenous variety. It is a good example of the methods adopted to impress the Oriental imagination. "In the Tinnevelly district the department had to resort to drastic action for the control of seed in the case of some ninety acres of *pulichai* [the inferior cotton] . . . the seed from this cotton was publicly burnt . . . before a large gathering of ryots."

In the improvement of Jute (of which India exports annually products worth 40,000,000*l.*) some notable advances have been made. It is expected that in the present year more than 30,000 acres will be sown with a new selected variety as a result of the distribution by the department of 500,000 packets of seed. In this connection a valuable scientific discovery may be mentioned. The pernicious weed, water hyacinth, which infests the waterways of Bengal, has been found to have a high potash content and is consequently a valuable manure for jute the use of which not only directly stimulates yield but also protects the plant against a Rhizoctonia disease which attacks it.

It will be readily admitted that this tale of economic progress is astonishing. No mention has been made of the purely scientific results achieved, and they are very considerable. The workers no doubt feel well rewarded by the satisfaction with which they must regard the additions to knowledge which they have made, but they may also feel some pride in the remarkable economic advances which their labors have brought about, especially in regard to the food-producing plants.—*Nature.*

[1]Report on the Progress of Agriculture in India for 1916-17. (Calcutta Supt. Govt. Printing, 1918.)

A New Method of Separating Slate from Coal*

That Promises Important Economies

By H. M. Chance

THE method and apparatus which is the subject of this paper has been invented and developed by Thomas M. Chance, of Philadelphia, a member of this Club, who is now in the National Service.

In order to illustrate clearly the difference between this new method for separating impurities such as slate, fire-clay, pyrite, etc., from coal and those in present use for this purpose, we will briefly review the types of apparatus now used in preparing coal for market.

HAND PICKING.

The most simple way in which to remove slate, etc., from coal is to pick out the impurities by hand, and in some localities all of the coal is prepared in this way. When this method is used the coal is allowed to slide down chutes, aprons, or "telegraphs" in the form of inclined troughs, along which boys or men are stationed to pick out the slate and other impurities; or the coal is transported by means of travelling belts or picking tables past the slate-pickers.

BRADFORD BREAKER.

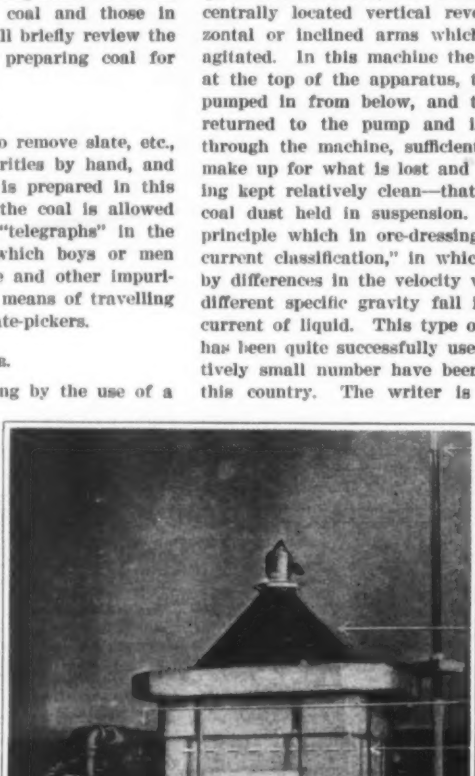
Coal is often prepared for cooking by the use of a "*Bradford breaker.*" This is a large slightly inclined revolving screen, which breaks the coal by continuously dropping it from shelves arranged lengthwise on the inside of the screen, the coal being thus broken to a size that permits it to pass through the screen perforations, while the slate or rock is not broken small enough to pass through the perforations and is discharged out of the lower end of the screen. Apparatus of this type can be used only when the coal is relatively soft and the slate is relatively hard or tough.

COAL WASHERS.

In the preparation of coal by washing, many different types of apparatus are used, the most simple of which is known as the "trough washer," which is merely an inclined trough or sluice with riffles on the bottom of the trough. The coal is fed in at the upper end of the trough together with a stream of water sufficient in volume to carry the coal over the riffles and down through the trough, but not sufficient to move the heavier materials, such as slate, which settle between the riffles or in pockets provided along the bottom of the trough. Automatic means for discharging the slate that accumulates in the pockets or riffles are provided in some trough washers, and some forms of washers are equipped with a flight conveyor working on the bottom of the trough, which continually scrapes the slate upwards in a direction opposite to the flow of the water, discharging the slate, etc., from the upper end of the trough. Other forms of trough washers have been used with spiral conveyors or other means of maintaining agitation of the coal to insure the more efficient separation and removal of the impurities.

The operation of trough washers is analogous to, if not precisely similar to, that of sluices used in the working of placer gold deposits.

Another type of washer, which employs a vertically rising current of water together with mechanical agitation to effect the separation, has been used and is usually termed the "*Robinson*" washer because the Robinson washer was the most highly developed machine of this kind. This machine consists of a large conical or funnel-shaped vat or tank with provision for trapping out the slate and other impurities from the bottom. Provision is also made for passing a large volume of water into the bottom of the tank so that the lighter material, *i. e.*, the coal, is buoyed up by the velocity of the ascending water and only the slate and heavy impurities sink to the bottom. To effect this result without the use of enormous and prohibitive quantities of water, the machine is provided with a centrally located vertical revolving shaft with horizontal or inclined arms which keep the whole mass agitated. In this machine the coal flows over the lip at the top of the apparatus, together with the water pumped in from below, and this water commonly is returned to the pump and is continuously pumped through the machine, sufficient water being added to make up for what is lost and to insure the water being kept relatively clean—that is, free from clay and coal dust held in suspension. This washer uses the principle which in ore-dressing is known as "upward current classification," in which separation is effected by differences in the velocity with which materials of different specific gravity fall in an upwardly moving current of liquid. This type of washer in some cases has been quite successfully used, although only a relatively small number have been built and installed in this country. The writer is under the impression, however, that very few machines of this type are now in use.



Experimental model of the coal separator

JIGS.

In almost all coal fields where coal is washed before shipment the appliance most used for this purpose is some type of jig. This may be described as a tank containing a horizontal or slightly inclined sieve or screen upon which the separation of the material is effected by vertical oscillations or pulsations of the body of water with which the tank is filled. These pulsations are produced by any suitable means, usually by a plunger or piston working in a compartment connecting with that in which the material is to be separated. In other forms the sieve or screen forms the bottom of a tray or box which is moved up and down rapidly, usually by means of rods by which the tray is suspended, which in turn are actuated by eccentrics or cams on a revolving shaft located above the tank. In both of these types of jigs the coal and slate are thus moved upwards and allowed to fall into the water, the heavier material sinking and forming a layer lying upon the screen or sieve and below the coal. The coal and slate thus separated are removed continuously or periodically by any suitable means.

Jigs work best on a closely sized material in which the individual particles are of approximately the same shape, and may fail to work on flat coal, which by turning on its edge may sink into the slate, or on flat slate, which if lying nearly horizontal may often be buoyed up and remain with the coal.

One of the difficulties in operating jigs is due to the fact that if the slate be drawn off too rapidly coal will also be drawn off and discharged with it, and, *vice versa*, if the slate be drawn off too slowly then a portion of the slate will be discharged with the coal.

One of the principal objections to the use of jigs in the preparation of coal for domestic use is the attrition to which the coal is subjected by being pounded up and down 60 to 180 times a minute from the time the coal is fed into the jig until it is discharged, a period commonly of from one to five minutes, depending upon the rate at which coal is being run through the machine. This results in the breaking of tender coal and in the chipping off of the corners of brittle coal, causing a material reduction in size and weight of the finished product. In the preparation of anthracite coal the jig loss—that is, the loss in weight of merchantable sizes, represented by the buckwheat, rice, barley and culm (small sizes of use only as steam coal and salable only at greatly reduced prices) caused by attrition in the jigs—has variously been estimated as ranging from 3 to 20 per cent.

"SLATERS."

Other mechanical devices for separating slate from coal are "spirals," "air-gap" slaters, and slot slaters. Spirals and "air-gap" slaters utilize the difference in velocity of coal and slate sliding down by gravity over an inclined surface. Slot slaters are used to separate *flat* slate by passing the coal over narrow slots through which the coal cannot drop but through which the flat slate can readily fall.

CONCENTRATORS.

Concentrating tables and bumping tables of various types similar to those used in ore-dressing have been used in washing coal for making coke, where, in order to eliminate the pyrite, it is necessary to crush the coal to fine size so that much of the material is too small to be treated successfully in jigs.

NEW METHOD.

All of these methods depend upon differences in the kinetic energy developed by the individual particles of material to be separated, or upon differences in the falling velocities of the individual particles in water when subjected to a force such as upwardly rising or pulsating currents of water. They may therefore all be classed together as *kinetic methods of separating*, while the method which will now be described can be termed a *gravimetric method*, because it depends upon difference in the specific gravity of the particles to be separated, and consists in immersing the materials to be separated in a fluid mass whose specific gravity is less than that of the heavier material and greater than that of the lighter material.

If we introduce coal, ranging in specific gravity, say, from 1.30 to 1.50, into a fluid mass whose specific gravity is 1.60, it is evident that all of the coal will float, and that if the coal contains particles of slate the specific gravity of which, for example, is from 1.70 to 2.40, all of the slate will sink. It is also evident that this separation will be entirely independent of the size or the shape of the individual particles of coal and of slate, because the smallest particles of slate will sink in such a fluid mass and the largest lumps of coal will float in such a fluid mass, and flat slate will sink and flat coal will float in such a fluid mass. In other words, there will be in this case no tendency to a buoying up of the particles of the materials by reason of the shape of the particles, such as occurs in jigs. It is also evident that when ma-

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terials are separated by introduction into such a fluid mass there will be practically no loss from attrition by the rubbing of particles upon each other, such as is experienced in the operation of jigs.

HIGH GRAVITY LIQUIDS AND SOLUTIONS.

Suggestions looking to the use of a specific gravity method for separating coal from slate and metallic ores from waste material have often been advanced, and many attempts have been made to find some liquid or fluid of sufficiently high specific gravity to be used for these purposes, and many experiments have been made to produce some such chemical solution of relatively high specific gravity.

It is, perhaps, unfortunate that there are no cheap and innocuous solutions known that are of high enough specific gravity for use in the commercial separation of slate from coal. A solution of zinc chloride is frequently used in the laboratory for experimentally determining the possibilities of separating coal and bony coal and slate in order to learn in advance of the building of a jigging plant as to what kind of a separation it may be possible to effect. The zinc chloride solution is admirably adapted to this purpose, but for many reasons it cannot be used for making commercial separations on a large scale.

The use of a solution of any kind, or of a liquid of high specific gravity, would be objectionable, because much of such liquid or solution would inevitably find its way into the pores and joint planes and cracks in the material to be separated and large quantities of wash water would be required to remove this material, and this would involve the loss of a portion of the chemicals used in making the solution. The use of such solutions would also probably cost much more than can be expended in improving the grade of fuels used for ordinary purposes. Other chemicals have been suggested and experimentally tried out on a laboratory scale, but the writer does not know of any examples of actual value in practice of chemical solutions of high specific gravity for the commercial separation of slate from coal.

HIGH GRAVITY FLUID MASS.

The present invention is based upon the fact that if any relatively finely divided insoluble material—such, for example, as sand—be mixed with a certain quantity of water and if the mixture be continuously agitated, the mixture will assume and preserve fluidic properties, and will exhibit the physical characteristics of a true liquid of high specific gravity.

If a mixture of sand and water in certain definite proportions be made and the mass be subjected to continuous agitation by means of stirring arms, propeller blades or any type of mechanical agitator, it is found that a fluid mass of definite specific gravity is produced. If the quantity of water be increased, the specific gravity of the fluid mass is decreased; if the quantity of water be decreased, or the quantity of sand be increased, the specific gravity of the resulting fluid mass is correspondingly increased. We have found in practice that such fluid masses can readily be produced by the use of sand similar to the seashore sand of the New Jersey coast, and with such mixtures we can in this way obtain fluid masses having specific gravities up to about 1.72. It seems theoretically possible to increase the specific gravity of the mass so obtained (by the addition of more sand) up to a gravity of about 1.80 more or less, and this may perhaps be possible in practice. The gravity can of course be reduced by increasing the quantity of water or decreasing the quantity of sand.

In producing and maintaining fluid masses of high specific gravity by this means, it is evident that mechanical energy must be supplied sufficient to counteract that which would be produced by the falling of the mass of sand employed through water of the depth used, so that the sand is raised and kept mixed throughout the mass of water and the tendency to

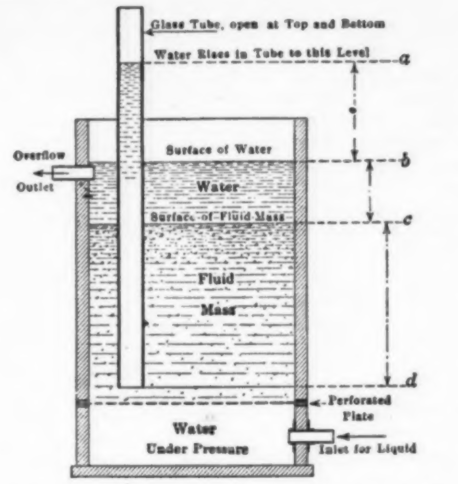
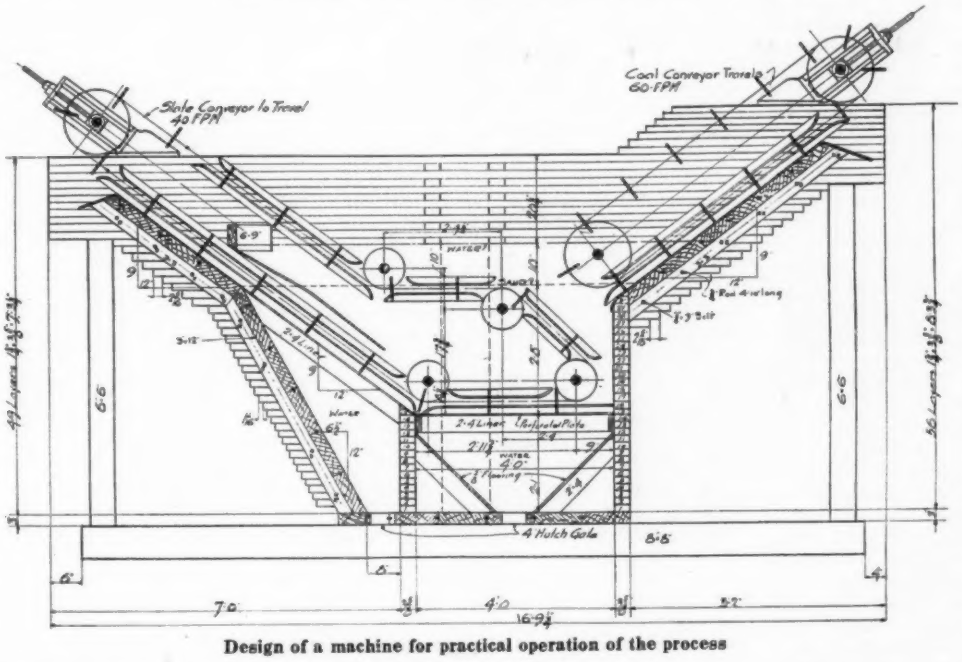


Diagram illustrating the working of the new principle

fall to the bottom is thus reduced, neutralized or eliminated.

It is, of course, evident that if sand heavier than seashore sand (which consists mainly of quartz grains), such as magnetic iron ore sand, be used, the resulting fluid mass will have much greater specific gravity, and we have found in practice that by the use of materials of this kind fluid masses of specific gravity sufficient to float quartz, feldspar, and other rock constituents (which constitute the gangue of metallic ores) can readily be obtained. In using such heavy gravity fluid masses in the treatment of ores the waste would float and the heavier or more valuable minerals such as copper, lead, or zinc minerals, etc., would sink to the bottom of the fluid mass.

It is not, however, intended to enter upon a discussion of the use of this method for the separation of ores from the waste, but to confine the paper to the separation of slate and other impurities from coal, and to demonstrate by the exhibition of a test cell the production of such fluid mass by the agitation of sand in water and to show the separation of slate from coal by the introduction of these mixed materials into the fluid mass contained in the apparatus.



Design of a machine for practical operation of the process

As the production and maintenance of such fluid mass is dependent upon continuous agitation to prevent settlement of the sand of which the fluid mass is composed, and is not dependent upon the way in which this agitation is produced, it is evident that any suitable means may be used for producing agitation. In the apparatus in which the demonstration will be made, agitation is produced by small hydraulic jets, *i. e.*, small jets of water introduced under pressure through perforations in the bottom of the receptacle containing the fluid mass. This type of apparatus, that is, one in which hydraulic jets are relied upon to produce the required agitation, seems best adapted for demonstration, because there are several features which can be illustrated more readily than in an apparatus where agitation is produced mechanically. It will be understood that while agitation may be effected by water pressure alone, either in the form of large or small jets acting upwardly or in any other desired direction, that a combination of hydraulic agitation and mechanical agitation can readily be used.

The apparatus exhibited consists of a water-tight wooden tank or box, 20 inches high and 6 inches by 8 inches inside dimensions, which is open at the top and is closed at the bottom with a brass plate 1/8 inch thick and perforated by round holes 1/16 of an inch in diameter and spaced one (1) inch apart, there being 48 such holes through which the hydraulic jets issue. Below this box and brass plate there is a wooden water-tight pressure box (of which the brass plate forms the top) into which water under pressure is introduced. The water issues under pressure through the small holes in the brass plate and maintains continuous agitation of the fluid mass contained in the apparatus. The apparatus is supplied with an overflow located about 3 inches below the top of the box, through which the surplus water is discharged. This overflow is directly connected with the suction of a small motor-driven centrifugal pump, and the delivery end of this pump is connected by piping with the pressure box at the base of the apparatus, so that agitation is effected by the continuous pumping of the same water from the overflow into the pressure box. The wooden tank or box is provided with two windows 5 inches square, one located near the top of the box and the other near the bottom, through which the action of the fluid mass and of any material floating upon it can be seen and studied.

In operating this apparatus to make the most satisfactory demonstration, the amount of sand introduced into the apparatus is such that at the pressure used, the top of the agitated fluid mass (consisting of a mixture of sand and water) will be at a point about one inch above the base of the upper window, because if the fluid mass be maintained at this height, we can study the action taking place through the upper window to best advantage. The fluid mass being maintained at this height, the clear water overlying the fluid mass from the surface of the fluid mass up to the water overflow is about four inches deep.

The pipe leading from the discharge of the centrifugal pump to the water pressure chamber at the base of the apparatus is provided with a valve to control the quantity and pressure of the water supplied to the pressure box, and a manometer gauge, consisting of a glass tube, is connected to this pipe near its entrance to the lower pressure box to measure the head of pressure under which the water is being supplied to the pressure box. The pressures under which the apparatus will be operated range from about twelve to twenty inches as the effective hydrostatic pressure by which agitation is effected. This is evidenced by the height to which the water in the glass manometer tube rises above the level of water in the apparatus as determined by the overflow pipe.

The specific gravity of the fluid mass will be reduced whenever pressure of the hydraulic water is increased such increased pressure resulting in a larger quantity of water passing into the apparatus supplying additional kinetic energy (agitation) and causing the level of the top of the fluid mass to rise. This rising of the top of the fluid mass indicates a dilution of the fluid mass by additional water and must of course result in lowering the specific gravity of the fluid mass as a whole, and *vice versa*, if the pressure under which water is supplied to the pressure box be decreased, the top line of the fluid mass will sink, and the specific gravity of the fluid mass will be correspondingly increased. It is further evident that so long as the quantity of sand in the apparatus remains constant and the hydrostatic pressure under which water is supplied to the apparatus for agitating such fluid mass be maintained constant, the specific gravity of the fluid mass will remain un-

changed. In other words, it is possible in this way to produce and to maintain a fluid mass of definite specific gravity for an indefinite period.

In demonstrating the action of the fluid mass in the apparatus in operation we now show the flotation of both anthracite and bituminous coal by putting into the apparatus pieces of such coal from one inch to three or four inches in diameter. It will be observed that the bituminous coal floats much higher out of the fluid mass than the anthracite coal, this result being naturally due to the fact that the anthracite coal is of much higher specific gravity (*i. e.*, heavier) than the bituminous coal. The coal which is being used for this demonstration is anthracite coal from the anthracite coal fields of Pennsylvania and bituminous gas coal from the Pittsburgh bed as mined by the Westmoreland Coal Company in the western part of the State of Pennsylvania.

This demonstration is sufficient to show how buoyantly the coal floats in such a fluid mass. If a lump of the coal be pushed down far below the surface of the fluid mass it rises to the surface very much as a block of wood will rise to the surface if immersed to some depth in water.

The extraordinary fluidity of this fluid mass of sand and water is not readily comprehended and no real conception of its fluidity can be obtained by a mere description. If the hand be plunged down through the superincumbent water into the fluid mass it is almost impossible to tell by any sensation one may experience as to when the fingers pass through the water and enter the fluid mass. In fact it has frequently happened that this experiment has been tried by an observer having his back to the machine so that he could not see the separating line between the water and the fluid mass, and in many cases the hand has been completely immersed in the fluid mass without the fact being detected or known to the individual who was making the experiment.

This fluid mass will float an hydrometer, and its specific gravity can be determined in this way. We have, however, incidentally discovered another method by which the specific gravity may be most accurately and definitely measured, and this consists in immersing a glass tube open at the top and bottom into the apparatus, so that the bottom of the tube is immersed ten or twelve inches below the top of the fluid mass. If the tube be held or secured in this position it will be found in a few minutes that the water will begin to rise in the tube until it has risen several inches higher than the level of the water in the apparatus. This is due to the fact that as the tube has no overflow, there is no upwardly rising liquid inside the tube, and the sand contained in the fluid mass within the tube gradually sinks to the bottom of the tube and joins the fluid mass external to the tube, so that the tube becomes filled with water, but as the water has a specific gravity of 1.0 and the fluid mass external to it has a higher specific gravity, the increased pressure at the bottom of the tube due to the higher specific gravity of the fluid mass forces water up into the tube until it finally stands at a height several inches above the top of the water in the apparatus. As the weight of the water overlying the fluid mass in the apparatus exactly balances the weight of the water in that part of the tube which is between the top of the water line and the top of the fluid mass, that portion of the water in the glass tube between these two points may be ignored, and we may say that the water in the part of the tube immersed in the fluid mass, that is to say ten inches, plus the height of the water in the tube above the water line, if added together represents the weight of a column of water which is sustained by the weight or pressure generated by the fluid mass from the top line of the fluid mass down to the base of the tube. If the tube be immersed in the fluid mass ten inches and the water in the tube rises six inches above the water line in the apparatus, then we have sixteen inches as the weight of water column which is supported by the hydrostatic pressure developed by ten inches of the fluid mass, and the specific gravity of the fluid mass is therefore sixteen divided by 10, or 1.60. Further, as the column of water six inches in height above the water line in the apparatus is supported by the increased weight of ten inches of the fluid mass and as this increased weight (or increased specific gravity) of the fluid mass is due to the weight of the materials held in suspension in said fluid mass, it is evident that this column of water six inches high measures the weight of the materials held in suspension in the ten inches of fluid mass measured from the top of the fluid mass to the base of the glass tube. It thus becomes possible to determine the weight of materials held in suspension in a fluid mass of this character without knowing the kind or character of such materials, that is, whether they be heavy or light, and whether they consist of grains of quartz sand or grains of magnetic iron ore.

We have constructed a small apparatus to show the actual separation of the slate from coal in this test cell which has just been described, and this consists of a square cage, the sides and bottom of which are made of one-quarter inch mesh brass wire screen. This cage is about eighteen or twenty inches deep from top to bottom and about four or five inches wide by six or seven inches long, and is closed at the bottom and open at the top. About six inches above the bottom it is provided with double folding doors, which when closed constitute a floor or partition. These doors are also made of one-quarter-inch mesh wire screen, and are provided with stiff wire rods by which they can be opened and closed. In using this cage to demonstrate the separation of coal and slate, the coal and slate to be separated are placed in the cage resting upon the double doors which are kept closed, and the cage is then lowered into the apparatus until the coal is immersed below the top of the fluid mass. The doors are then opened by releasing the wire rods holding them in place. Upon opening the doors the slate sinks through the fluid mass to the bottom of the cage, while the coal remains floating in the fluid mass at or near its top. The double doors are then closed by bringing the wire rods back into their original position and the cage is then removed from the apparatus. In bringing the cage up out of the apparatus it is slightly shaken while being passed through the water overlying the fluid mass in order to wash off any sand which may be adhering to or resting upon the coal. Upon thus removing the cage the coal is found resting upon the doors in its original position, but the slate is found in the bottom of the cage. The coal can then be emptied from the cage and after this is removed the doors can be opened and the slate removed for examination.

The author then made a demonstration with the apparatus, separating anthracite coal from slate, by placing in the cage a quantity of chestnut coal and slate, immersing the cage in the fluid mass as described, removing the cage and emptying the coal and slate into separate pans, the whole operation being completed in about fifteen seconds. The separation was perfect, the coal containing no slate, and the slate containing no coal, and the separated products were passed among the audience for examination.

The test cell used to illustrate this paper and by which the demonstration has been made was constructed for experimental purposes in determining the volume and quantity of water required to operate the method with different kinds of material and when agitation is produced by hydraulic water. It is not intended as a model of a machine such as would be used for the commercial separation of slate from coal, because it is not provided with means for mechanically removing the coal and slate after separation is effected. Machines for operating this method can be constructed to operate continuously, the material, coal and slate, being fed in at one point and after the slate has been separated the coal can continuously be removed, while the slate can also be continuously (or periodically) removed from some lower portion of the apparatus.

The commercial development of the method is now being pushed in two or three directions and I am able to show a design of a machine the construction of which is now practically finished and which we expect will soon be installed for regular work in the separation of coal from slate. This design is not intended to illustrate the best or only method of constructing such machines, but to show the general principles involved in the construction of machines for commercial use. This machine is designed to be operated mainly by hydraulic agitation. It will be observed that the coal is fed into the machine at the top line of the fluid mass by a flight conveyor of standard type, and this same flight conveyor carries the coal gradually across the machine, while the lower run of this same conveyor is used to remove the slate. A second flight conveyor is used for removing the coal from the machine. While hydraulic agitation by means of perforations in the base is mainly relied on in this machine, a certain degree of mechanical agitation is also obtained by the use of the flight conveyors and this will tend to prevent any banking or accumulation of sand in those portions of the machine in which separation is taking place.

In operating this machine certain supplemental devices will probably be used in the nature of sprays, located at or near the points at which the coal or slate is being discharged, to wash off the particles of sand that may adhere to either the coal or slate. Most of the sand will be washed from both the coal and the slate as these materials are being transported diagonally upwards through the layer of water which overlies the fluid mass. It is also probable that pipes may be used inside the machine provided with perforations for supplying water under pressure, *i. e.*, jets, and placed in such position that the jets will be directed upon the coal and slate as it is drawn up through the fluid mass and through the water overlying the fluid mass. These pipes can be submerged in the water underlying the fluid mass or in the fluid mass itself, and used for the purpose of obtaining supplemental agitation and of directly washing sand from the slate and from the coal, thus reducing the quantity of sand carried along with the coal and slate by the conveyors used in removing these materials.

While in the apparatus shown hydraulic agitation is effected by means of a perforated bottom, it will be understood that effective agitation can be obtained by jets from pipes inside the main tank and that these jets may be directed vertically downward, or at any desired angle.

The mechanical energy required to maintain agitation is surprisingly small. The quantity of water used in the apparatus shown is approximately about 1.3 to 1.6 gallons per minute or at the rate of about five gallons per minute per superficial square foot of area of the agitated fluid mass. The water is supplied under a hydraulic head of about fifteen to eighteen inches, and the fluid mass has a depth of about thirteen inches. The mechanical energy required to maintain agitation in this test cell is say 1.5 gallons (or say twelve pounds of water) per minute under a head of 1.5 feet, or about eighteen foot pounds or 1/1833 (one-eighteen hundred and thirty-third) part of a H.P., or at the rate of 3/1833, or say 1/600 (one-six hundredth) part of a H.P. per superficial square foot of surface. If the depth of the fluid mass be increased to three feet the requirement would be about 1/200 H.P. per superficial square foot of the area of fluid mass used.

It is of interest to note the possibility by this process of separating coal from "bony" coal, and of separating "bony" coal from slate, neither of which can be successfully done by jigs. It is possible to adjust the specific gravity of the fluid mass so that all "bony" coal rich in carbon will float with the coal, while bony coal that contains little carbon will sink with the bituminous coal to make a "three-part" separation, slate. In the same way it becomes possible in treating viz.: 1, highest grade coal, low in sulphur and ash and especially valuable for making by-product coke or for domestic use; 2, coal of medium grade as to sulphur and ash and suitable for general use as steam and heating fuel; 3, slate, fireclay, pyrite, and other impurities. A supplemental separation of the pyrite (for sale and use in sulphuric acid making) from the slate, fireclay, etc., can be made when the quantity of pyrite is sufficient to justify the additional cost.

It will be observed that the separation made by this method is a *perfect* separation; that the slate contains *no coal*, and the coal contains *no slate*, a result impossible to obtain with any method of separation in use.

It will also be evident that the mechanical energy required to operate machines of this kind will be far less than that required to operate jigs, and that the breakage from impact and attrition will be almost completely eliminated.

Naming Mountains in India

An article in the *Geographical Journal* discusses some important points in the nomenclature of Himalayan peaks. It is the practice of the Survey of India to veto all names and employ only numbers to designate peaks. Mount Everest is the only exception. Even Godwin-Austen is not allowed in place of K^2 or its modern synonym Pk. 13/52A. Most of the peaks have no native names, and the difficulty in giving names seems to lie in finding ones that will harmonize with such as exist. The Survey of India rightly objects to trivial names which are out of keeping with the ranges as a whole. Cathedral Peak, Broad Peak, and so forth may be appropriate locally, but are unsuitable continentally, and in any case are not specific. The numbering of peaks on the system now adopted has the merit of indicating the degree-sheet on which the peak occurs. In the example cited above, 52A is the number of the degree-sheet and 13 the number of the peak. On the other hand, the system has obvious defects, the greatest, perhaps, being that numbers are difficult to remember, and give anonymity to the peaks. Mr. Hinks suggests eight figure-numbers giving altitude and longitude. That would involve greater precision, if a severer test of the memory, but introduces complications where two peaks lie close together and seconds have to be added. No doubt in time many of these peaks will receive names, despite official disapproval.

Meteorology in Relation to Aeronautics—I

A Review of the Data Required by an Aviator When in the Air

By W. H. Dines, F.R.Met.S., F.R.S., Fellow

The ordinary data that are observed at a meteorological station are the following: The temperature, the barometric pressure, the humidity, the rainfall, and the strength and direction of the wind. These elements are recorded at many stations by automatic instruments, at other stations eye observations are made at stated hours each day, so that there is at the present time a vast accumulated mass of information, more indeed than some think is needful, and the mean value of any of these elements at any time of the day or year and in any part of the British Isles is fairly well known. Observations are also made of the current phenomena such as fogs, thunderstorms, snow, etc.

I propose to take these data in order and consider their bearing upon aviation. They are readily obtainable at the time and place of starting, but the aviator requires them for the height up to which he proposes to fly and for the future time during which he is to remain in the air.

THE TEMPERATURE.

The temperature of the air is not of itself, perhaps, of very great importance though the cooling of the engine and the comfort of the airman depend upon it to some extent but the temperature has more effect upon the density of the air than any other element, except the pressure, and since the lifting power of the machine for the same speed varies as the density, and also a correct measure of the height depends upon the temperature being known, it is necessary to discuss first the conditions that usually prevail.

It is and has been for long past perfectly well known that an increasing height is in general accompanied by a falling temperature. Even in the Tropics it is possible to reach the level of perpetual snow on the mountains; and in Scotland, although none of the mountains are high enough to reach the snow line, yet in many places the winter drifts do not entirely melt so that snow may always be found.

The reason for this decrease of temperature is fairly simple. As air comes under the decreased pressure of a higher level it expands, and expanding air is cooled by its own expansion. The converse process is apparent to a person using a bicycle pump, the air has to be compressed to be driven into the tyre, the compression occurs in the lower part of the barrel, which in consequence may become too hot to touch. The whole process is known as dynamic heating and cooling and to it chiefly the fall of temperature with height is due, although some small part of the effect may be due to the laws of radiation. The fact that the upper layers of air are nearer the sun is sometimes brought into the discussion of this question. It seems almost superfluous to point out that the few miles difference of distance is utterly insignificant in comparison with the distance of the sun, viz., ninety million miles.

The following figures give a general idea of the fall of temperature with height. Like all other figures given in this paper, unless the contrary is expressly stated, they refer to England, and more particularly to the South-East of England, but they will hold without much error for latitude 50° to 55° N.

TABLE I.

Height.		Temperature.			
Kilometers.	Feet.	Jan.	April	July.	Oct.
Surface	—	276	82	89	83
1 ...	3,281	71	76	83	79
2 ...	6,562	67	70	78	75
3 ...	9,843	63	65	73	70
4 ...	13,124	57	59	67	64
5 ..	16,405	50	52	61	58
6 ..	19,686	43	46	55	51
7 ...	22,967	37	39	47	45
8 ...	26,248	30	32	41	38
9 ...	29,529	24	26	34	31
10 ...	32,810	20	22	26	24
11 ...	35,091	17	19	22	20
12 ...	39,372	17	20	22	19
13 ...	42,653	16	21	23	18
14 ...	45,934	16	21	22	17

The temperatures are given for a reason subsequently explained in absolute measure, C., with the first 2 omitted. On this scale 273 is the freezing point, 50° F. corresponds to 283°,—4° F. to 253°, 40° F. to 233°, and —67° F. to 218°.

The fall of temperature for a given height is called the temperature gradient: but inasmuch as the term "gradient" is so commonly applied to changes occurring in a horizontal direction it seems better to avoid the term to denote a change in the vertical direction and hence "lapse rate" has been suggested. The lapse rate is usually measured in degrees centigrade per kilometer because the observations have very largely been made in connection with an international scheme and uniformity of units is essential. A rate of 10° C. per km. is equivalent to 5.49° F. per 1,000 ft.

The case when the temperature rises instead of falls with increasing height is called an inversion; inversions are common in the lower strata and the fall of temperature nearly always ends with some sort of an inversion at a height between 8 and 13 kms. (5 and 8 miles).

Broadly speaking, the average lapse rate up to 30,000 ft., the only part of the atmosphere with which we are concerned, is the same all the world over, so far as we know, excepting where the temperature is very low, as it is in Canada, Siberia, etc., in the winter. Very low temperatures with calm and a clear sky nearly always, perhaps always, have an inversion over them, so that although the winter temperature in Russia is much below that in England, at 6,000 ft. the difference is not nearly so large. Near the equator the lapse rate for the first few kilometers is about 5° per km., increasing to 7° or rather over at higher levels just as in England, but over the Tropical regions the fall is continued to a much higher level, to 16 or so instead of to 10.5 km. as over England, with the result that the lowest natural temperatures ever registered have been found at a height of 10 miles over the equator. There are not enough observations to give a very accurate mean value, but it is about —80° C., whereas over England it is —54° C.

The values in the table are for England. The annual range that we have at the surface is seen to extend upwards to about 10 to 11 kms., say 7 miles, or 35,000 ft. The times of the lowest and highest temperature in the South-East of England at the surface occur in January and July, but above some 5,000 ft. these dates occur about a month later. Thus, other things being equal, the temperature decreases with height more rapidly in the spring than in the autumn months. The difference, however, is not great enough to be of much practical importance.

The daily range of temperature is quite small at a few thousand feet above the earth's surface, as indeed it is also over the sea, but it is large at inland stations in clear weather near the ground. The lapse rate in the first few thousand feet is therefore very dependent on the time of day. About sunrise in calm clear weather there will nearly always be an inversion in the first thousand feet, so that an aviator will rise quickly into warmer air. On the other hand, on a sunny afternoon in late spring or summer the fall of temperature for 3,000 ft., perhaps for 5,000 or 6,000 ft., will be as great as the conditions of equilibrium permit. This rate, known briefly as the "dry adiabatic"—it refers only to air in which clouds are not being formed—is 1° C. per 100 meters, or 1° F. per 190 ft.

The lapse rate also depends upon the height of the barometer, being much greater in the lower strata when the barometer is low than when it is high. With a deep cyclonic depression, barometer 29.00 at mean sea level, the probable temperature at 7 km. height (23,000 ft.) is —39° C., whereas with an anti-cyclone, barometer 30.30, it is probably —27°, a difference of 12° C. (21.6° F.), about equal to the difference between January and July. With a low barometer the lapse rate is large up to say 9 km., but ceases there, with a high barometer the lapse rate is small up to 5 kms., there is in most cases an inversion somewhere under 6,000 ft., but the fall of temperature is continued to say 12 kms., or maybe 13 kms., with the result that the upper part of the atmosphere, a part far beyond the reach of any aeroplane, is much colder over the anti-cyclone than over the cyclone.

An inversion of temperature is found, too, I believe invariably, over a certain type of stratus cloud. At least, on every occasion on which I have succeeded by means of kites or balloons in getting an observation, an inversion has been found. An inversion is not, however, present over every cloud sheet. The type of cloud I mean is a thin cloud, generally with gaps in it, which permit stars or the moon near the zenith to be seen, but do not permit the winter sun, on account of its low altitude, to be seen. It is common in winter when the barometer is high.

THE BAROMETRIC PRESSURE AND THE DENSITY.

The aviator is affected by the barometric pressure in many ways. The density on which the lift exerted on the wings of his machine depends is proportional to it, the running of his engine is influenced by it, and his aneroid, which purports to show him his height, although the scale may be marked in feet, really shows him the pressure and nothing else. His speed indicator also depends on it.

The direction and strength of the upper wind depend upon the distribution of pressure, but this matter will be considered under the heading "Wind."

The barometric pressure is simply the weight of the overlying air. The air consists of a mixture of various permanent gases, the proportions in which these gases are mixed being constant, together with a certain quantity of water vapor, the proportion of which to the whole is very variable. But the actual percentage of water vapor in the air in these latitudes is small and its effect upon the density is trifling and we may in this connection neglect it without serious error.

The average barometric pressure at sea level is about 15 lbs. on each square inch, which means that if we take a column of air of 1 sq. in. cross section reaching up from sea level to the top of the atmosphere the air in such a column will weigh 15 lbs. At greater heights the overlying column is of course shorter and therefore of less weight, and the problem of determining the height of an aeroplane is that of knowing what weight of air corresponds to a given length of air column. The altimeter, as previously stated, measures only the pressure, and the difference of pressure must be translated into length of air column. This would be easy enough if only the same length of column always corresponded to the same difference of pressure, but this is not the case.

What is actually done is to assume certain definite conditions, but these conditions are not always found, and when they are not found a correction is required.

This was of some importance in days when an acute competition to attain the maximum height was in progress. As Captain Tizard pointed out (*Aeronautical Journal*, April-June, 1917, p. 109), the real test is to reach the lowest density, and the same density is not always found at the same height. But the public understand what is meant by height, but not what is meant by density, and therefore the competition to hold the record for height is likely to continue.

For convenience of reference the formula connecting the pressure and the height and the simple principles on which it rests are set out below.

The pressure, temperature, and volume of a definite quantity of the atmosphere are connected by the equation PV/T equals a constant, where P is the pressure, V the volume, and T the temperature on the absolute scale. This is an experimental fact and is commonly known as the gas equation. If we prefer to measure temperature on the Centigrade or Fahrenheit scale for T we must write $273+t$, where t is the temperature Centigrade, or $455+t$, where t is measured in degrees F. The gas equation is of such constant use in theoretical meteorology and in physics and it is so much more convenient to have a single term T to deal with than a compound term like $273+t$, that it is becoming usual to measure and record temperatures in the absolute scale.

The density of a body is its mass divided by its volume. Since in the gas equation we are considering the changes of pressure, etc., of a definite amount or mass of air, if we introduce the density (D) instead of the volume, since $D=M/V$, the equation takes the form

$$P/DT = \text{a constant.}$$

That is the density of a gas varies directly as the pressure and inversely as the absolute temperature. At the surface variations of pressure to the extent of 4% below and 2% above its mean may easily occur; and variations of temperature over the range 20° to 80° F., giving 6% on either side, may equally well occur. It so happens that very high temperatures and low heights of the barometer do not occur simultaneously, but variations of density to the extent of 8% from the mean on either side are not impossible. The variations of density at heights above 5,000 ft. are very much smaller; this is because it is the general rule that from that height upward to 30,000 ft. high pressures and high temperatures occur together and conversely, so

*A paper read before the Aeronautical Society of Gt. Britain, and published in the *Aeronautical Journal*.

that the two causes of variation act in opposite ways and partly cancel each other out.

Since in an aeroplane the pressure can be got with fair accuracy from an aneroid and the temperature from a thermometer the density can be determined. A knowledge of the density is necessary before the proper correction can be applied to the speed indicator, the indications of which depend directly on the density.

To obtain the true height is much more difficult and requires a knowledge of the temperature not only at the point, but at each step of height upward from the ground. The formula connecting pressure and height is obtained thus. If we consider a height h above sea level the difference in pressure between sea level and the height h is the weight of the intervening column of air. This weight is proportional to the density—that is, as shown above, it is proportional to the pressure and inversely proportional to the absolute temperature. But neither the pressure nor the temperature is the same at the top and bottom and we must therefore calculate the height by steps, taking h so small that we may without appreciable error use the mean values of P and T over the column. If we assume T constant we can take account of the variation of P and obtain an exact formula thus:

Consider a column of air of cross section A at the bottom of which the pressure is P. Then ascend a very small height δh to a point where the pressure is $P-\delta P$. The whole pressure on the bottom is AP and the whole pressure on the section at the height δh is $A(P-\delta P)$. The difference $A\delta P$ is the weight of air in the length δh of the column. The weight equals the mass × acceleration due to gravity and the mass is the volume × the density. The volume is $A \times \delta h$, hence $-A\delta P = gDA\delta h$. The density equals kP/T where k is some constant.

Hence

$$-\delta P = gk\frac{P}{T}\delta h$$

$$\text{or } \delta h = -\frac{T}{gk}\frac{\delta P}{P}$$

Integrating

$$h = -\frac{T}{gk}\log_e P + \text{a constant.}$$

Let h be measured from sea level at which the pressure is P_o, then to determine the constant we have $h=0$ when $P=P_o$.

$$\therefore h = \frac{T}{gk}(\log_e P_o - \log_e P) = \frac{T}{gk}\log_e\frac{P_o}{P}\ (T).$$

We can change to common logarithms by dividing by 2.3026, hence, $h=\mu T \log P_o/P$ when μ is a constant dependent on the units in which h is measured. In feet $h=221.13T \log P_o/P$, and it will be seen that as the ratio of the pressures only is involved the unit in which they are expressed is immaterial. As an example, suppose there is a uniform temperature of 50° F. which is equivalent to 283° A, and that the barometer stands at 30.00 in., to find the height at which we have the barometer at 27.00 in. we have $h=221.13\times 283\times\log. 1.11111=2{,}863$ ft.

When integrating to obtain equation (1) it was assumed that T was constant, but in actual practice the temperature is arbitrary and bears no fixed relationship to the pressure. For the actual conditions therefore (1) is not rigorously exact, but the error will be inappreciable, not more than one foot in a thousand, if the mean temperature of the column be used and if h does not exceed 10,000 ft. For heights of the order of 30,000 ft. the error, even if the correct mean temperature be used, may reach nearly 1 per cent. Hence, for great heights the only way is to proceed by steps, determine the pressure at say 10,000 ft. and then use that for the starting point for the next 10,000, and so on.

In the "Computor's Handbook," published by the Meteorological Office, tables are given showing the factor for all temperatures between 200 and 300 A by which the pressure at any height must be multiplied in order to obtain the pressure at the point one kilometer higher. The effect of the humidity and the variation of gravity is also shown.

In equation (1), if h is put equal to 1,000 ft. the ratio P/P_o for any assigned value of T is readily obtained. The values for a few temperatures are shown below, and by multiplying the pressure at any height by the given factor the pressure 1,000 ft. higher is obtained.

Temperature	Factor to give pressure 1,000 ft. higher
200	.9505
210	.9529
220	.9551
230	.9571
240	.9589
250	.9605
260	.9620
270	.9635
280	.9648
290	.9661
300	.9672

Captain Tizard has given (*Aeronautical Journal*, April-June, 1917, page 110) a table of average densities at each 1,000 ft. up to 20,000.

From what has been said above about the variations of temperature and the manner in which the pressure at any precise height is dependent on the pressure at the ground and on the temperature between the ground and the height considered, it will be seen that when no temperature observations away from the ground are available, to determine the precise value of the density is impossible. But we can advance a stage beyond being content with the average value. We might prepare tables giving the average for each month, but this would not be satisfactory since it would ignore the conditions of pressure and temperature prevailing at the time, conditions which are important and easily measured.

The lapse rate, apart from its daily variation at inland stations in the first kilometer, is the least uncertain of the different variable elements which define the atmospheric conditions and on this basis I have prepared a table of corrections in terms of the pressure and temperature at the surface to be applied to Captain Tizard's values of the average density.

It is too long to go into details, but from some 200 observations made in the southern part of England tables have been prepared showing the fall of temperature between the ground and various heights in terms of the height of the barometer; from these tables by the ordinary statistical method of calculation the most probable value of the pressure and temperature at any point up to 30,000 ft. has been found and from thence the density.

TABLE II.

Percentage additions to be made to the density at different heights to allow for variations from the mean of the surface pressure and the surface temperature.

Height.	Pressure difference in inches at surface.	Temperature difference in degrees F at surface.
Surface	+.033	—.0020
2,000 ft.	+.026	—.0018
4,000 ,,	+.020	—.0017
6,000 ,,	+.016	—.0016
8,000 ,,	+.013	—.0015
10,000 ,,	+.012	—.0013
12,000 ,,	+.011	—.0012
14,000 ,,	+.011	—.0011
16,000 ,,	+.012	—.0009
18,000 ,,	+.013	—.0008
20,000 ,,	+.015	—.0006
22,000 ,,	+.017	—.0005
24,000 ,,	+.020	—.0003
26,000 ,,	+.025	—.0002
28,000 ,,	+.033	—.0000
30,000 ,,	+.044	+.0002

The values are given in percentages so that they may be applicable to any units in which the density is expressed. The mean sea level pressure in the South-East of England is a little over 760 m.m., or a little under 30.00 inches of mercury. The mean temperature is 50° F., 10° C., or 283° A. Thus, if we require the most probable density at 10,000 ft. when the barometer is 29.50 and the surface temperature at 32° F., proceed thus: 29.50 is .50 in. below the pressure mean, the correction is therefore —.012 × .50 = —.006. The temperature is 10° below, and the correction is + .013. The whole correction is + .007 and we must multiply the average density by 1.007.

For heights of and above 4,000 ft. this table is probably the best that can be done under the present state of our knowledge, and it should in most cases give the density within one per cent., but the following remarks are necessary:

Over the open sea or at a coast station, with a fairly strong wind off the sea, the surface temperature at the start is to be used. At an inland station or a coast station with an off-shore wind, the mean temperature for the day is to be used in preference to the surface temperature at the time, because the latter is purely local and depends so largely on the time of day.

The correlation coefficients between the lapse rate and the height of the barometer on which Table II is based range as a rule from .30 to .50, they are not large enough to make the estimate very reliable, but they are sufficiently large to make it worth while to take the surface pressure into account. There are so many variable quantities involved that the question is very complicated, and it is perhaps of more importance for long range artillery fire than for aeronautics.

THE HUMIDITY.

The humidity is an important matter for aviation inasmuch as fog, clouds, rain and snow depend upon it. But the value of the humidity is only of use for the forecasting of fog, and this matter has been so fully dealt with in a lecture given here on February 28th, 1917, by Major Taylor, that I have nothing further to say about it. Instead, therefore, of wasting time on the subject I will refer to his remarks, published in Vol. XXI., p. 75 of the *Aeronautical Journal*, and also to a paper by Capt. Cave, published in the same volume, p. 301, in which the dangers due to rain and snow are mentioned.

(To Be Continued.)

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